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Nuclear Power

REACTORS · MATERIALS · INSTRUMENTATION · PROCESSES · IRRADIATION

VOL 6 NO 57 JANUARY 1961

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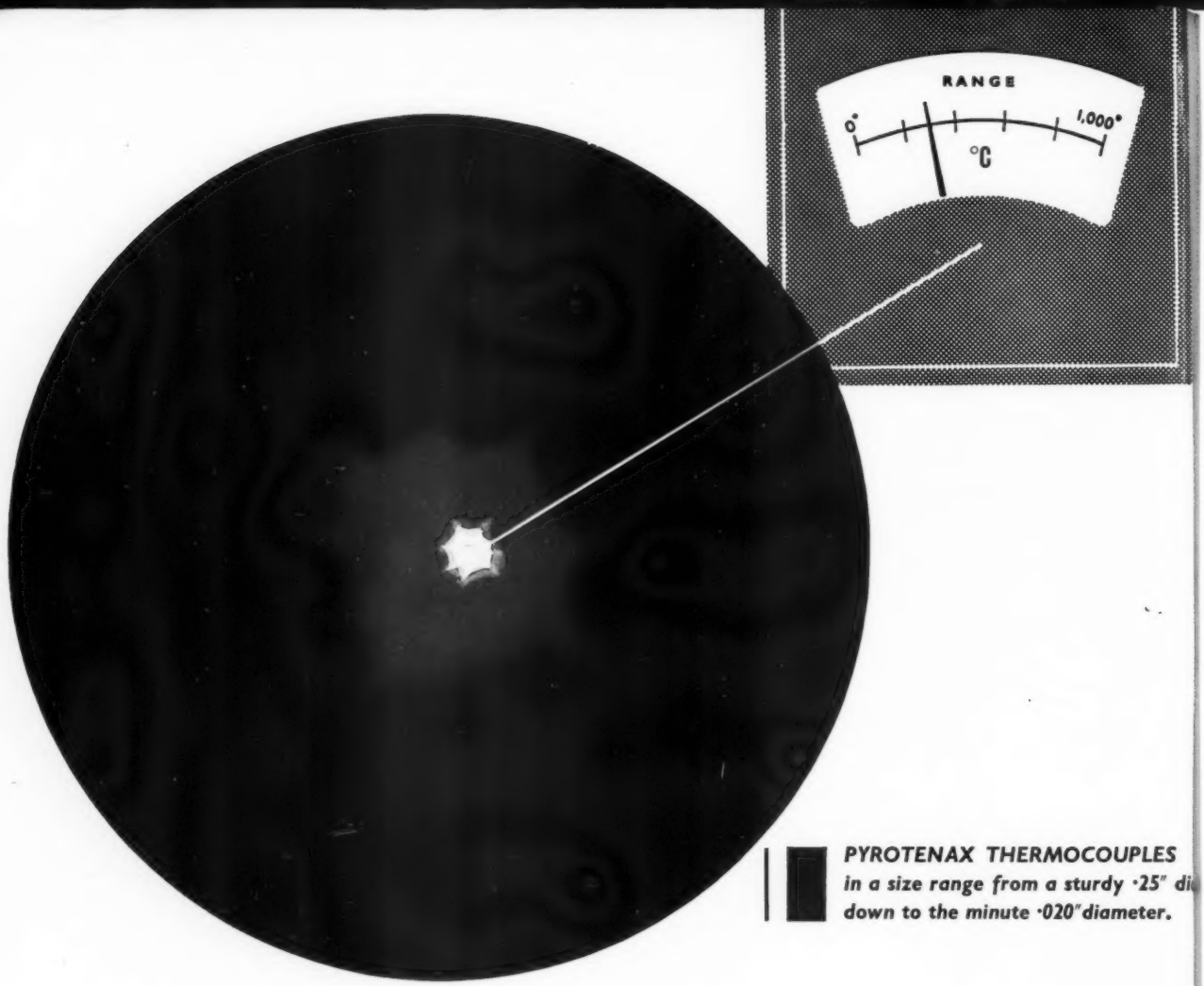

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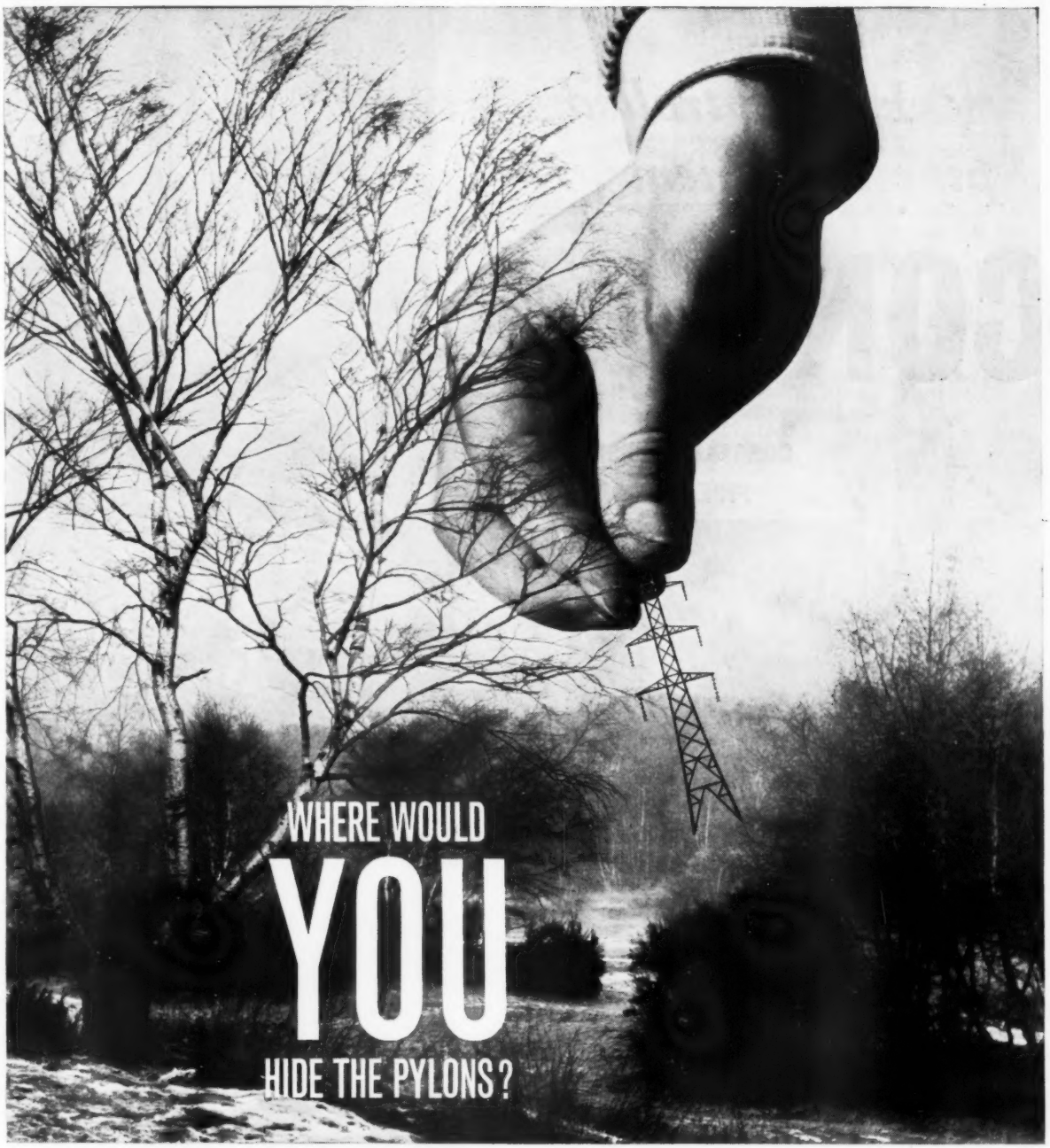

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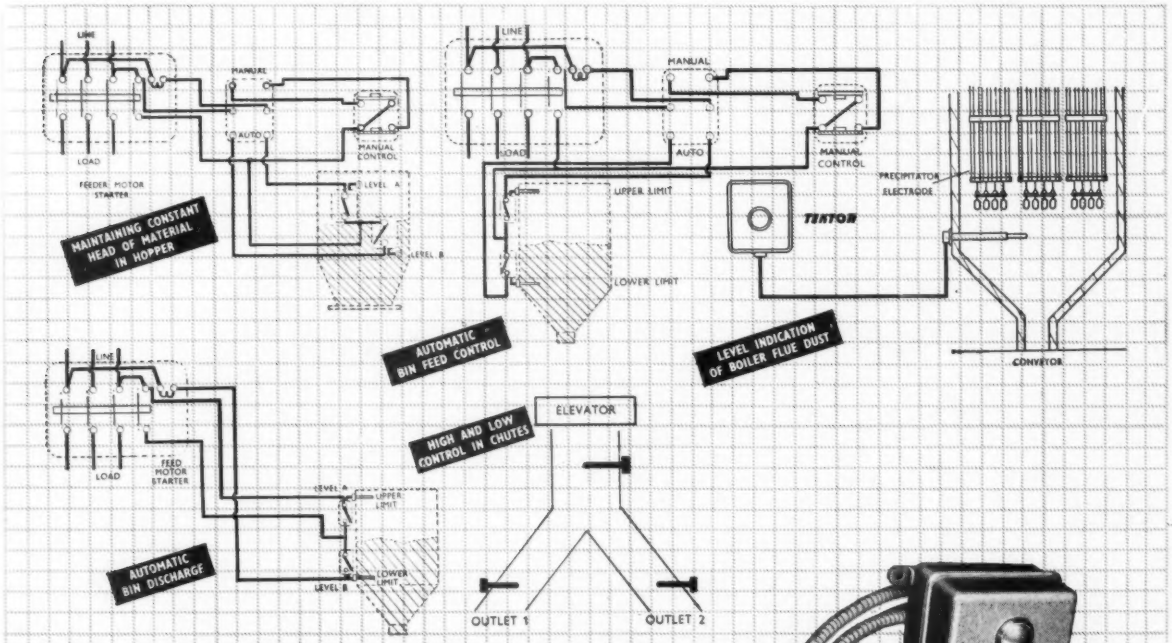

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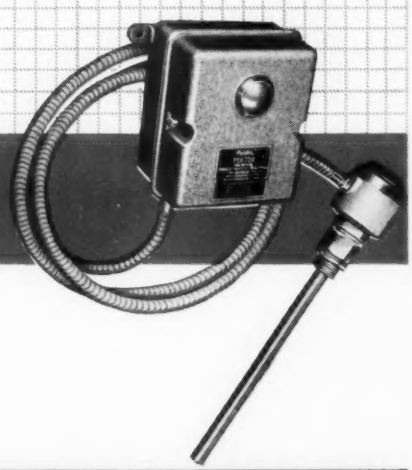

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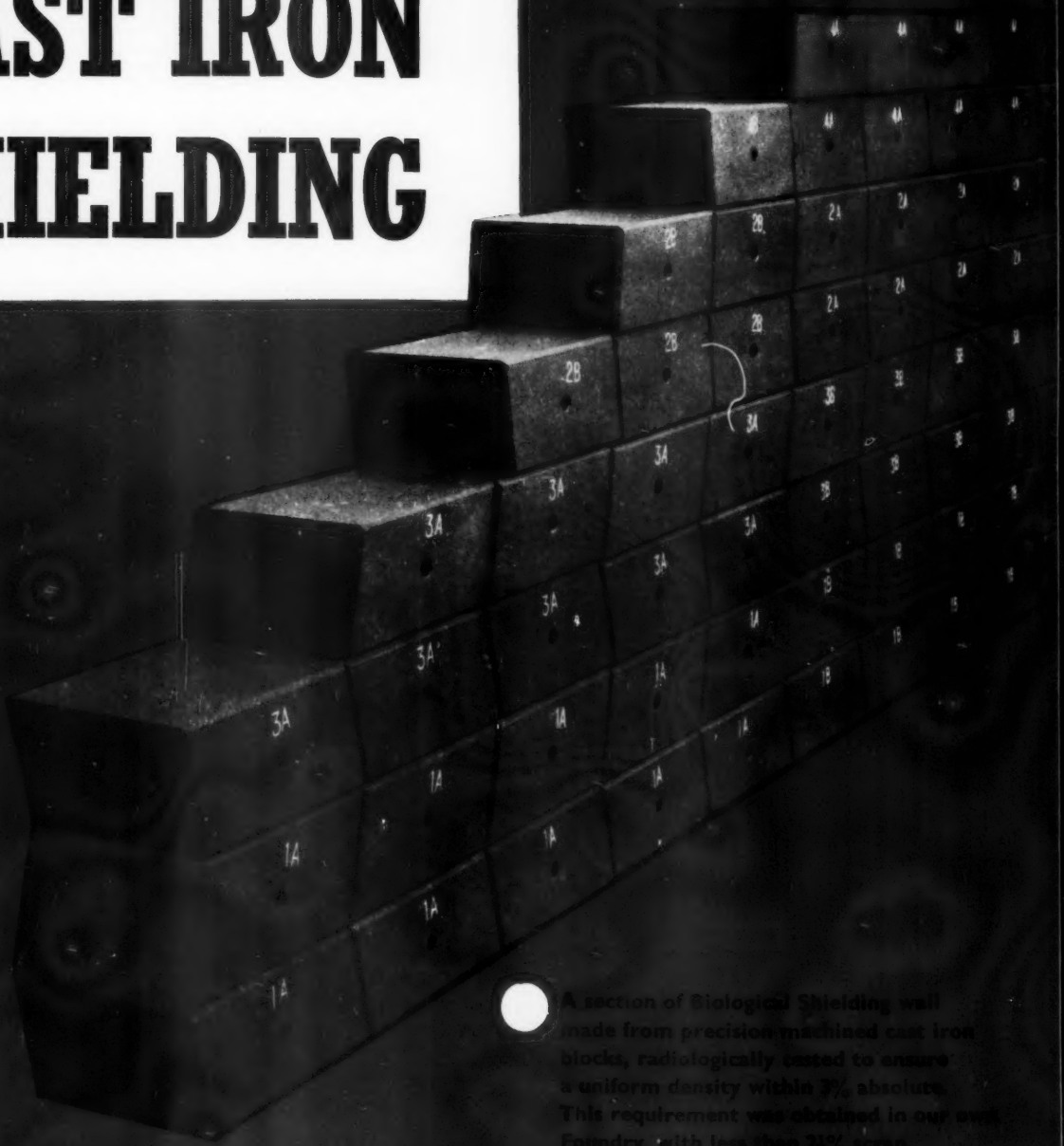

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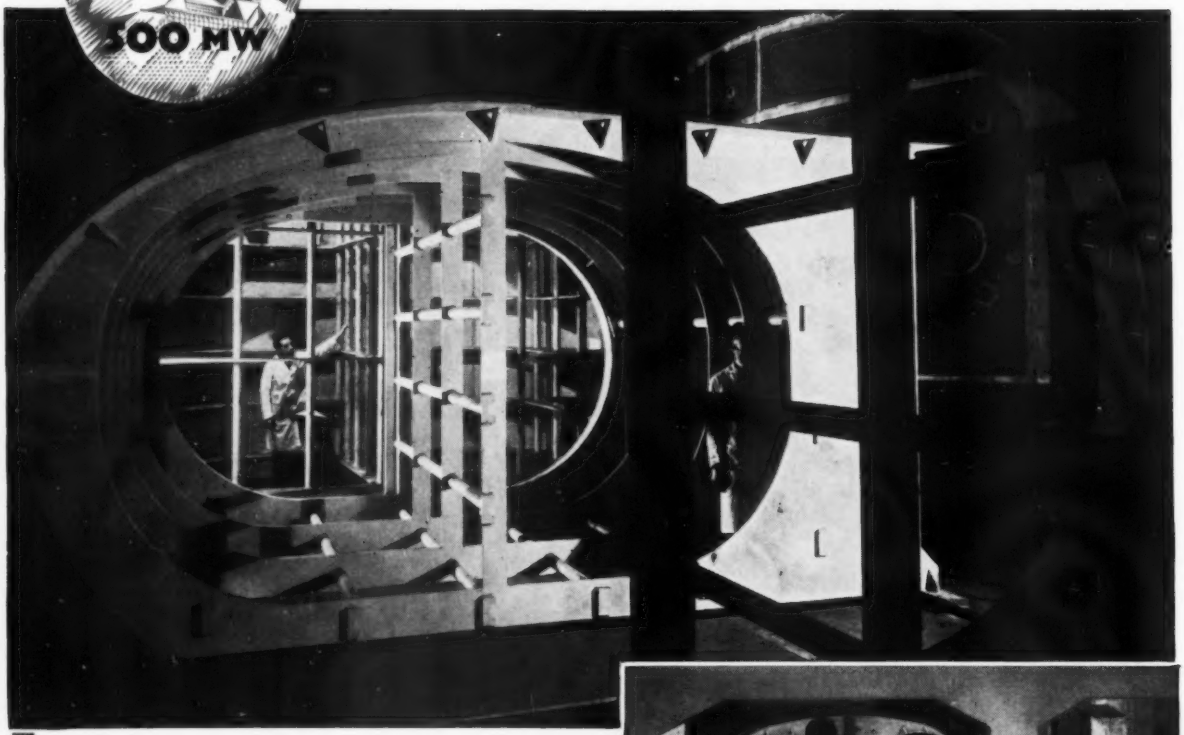

Rapid progress is being made at the Hinkley Point 500 MW atomic power station now under construction for the Central Electricity Generating Board. On schedule, too, at the works of The English Electric Company is the building of the 6 main and 3 auxiliary turbo-alternator sets and ancillary equipment.

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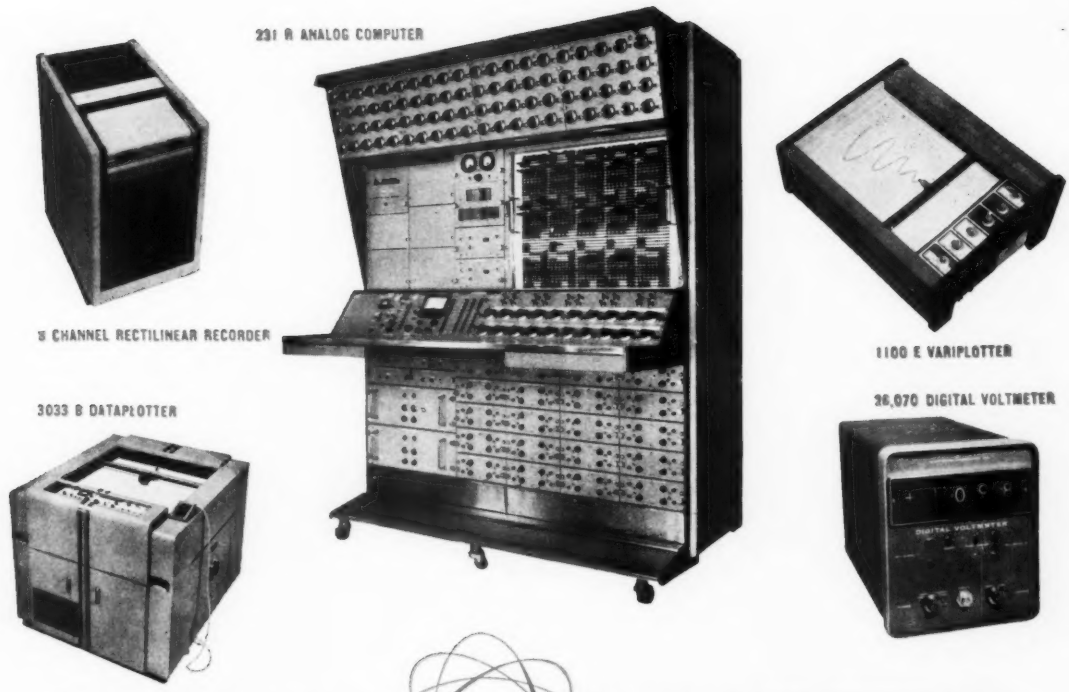

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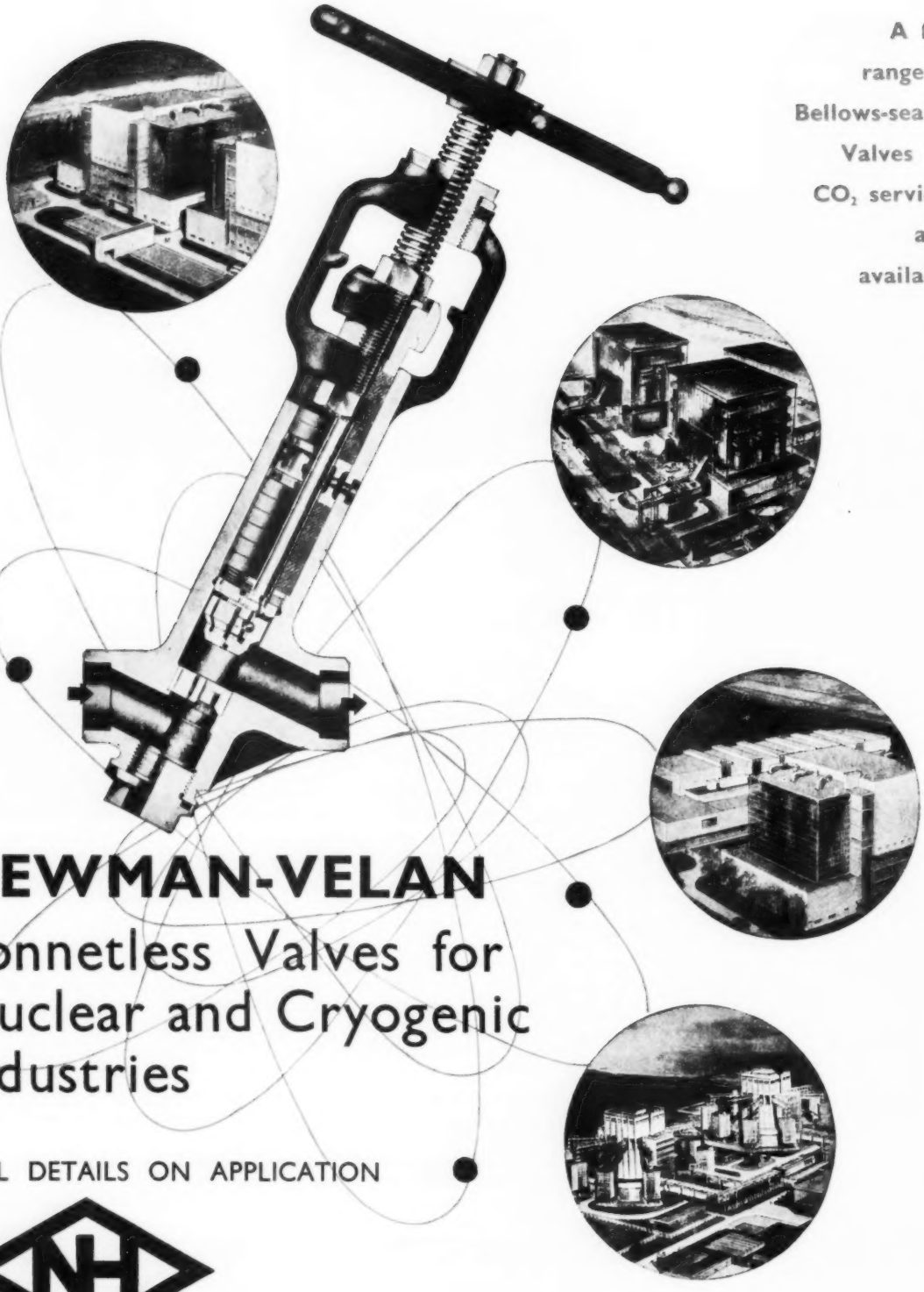

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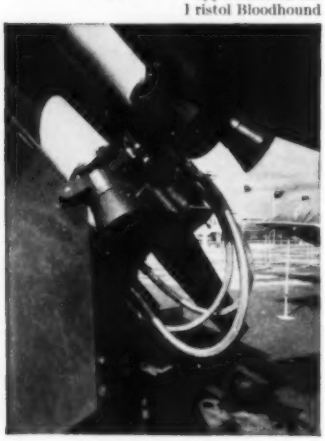

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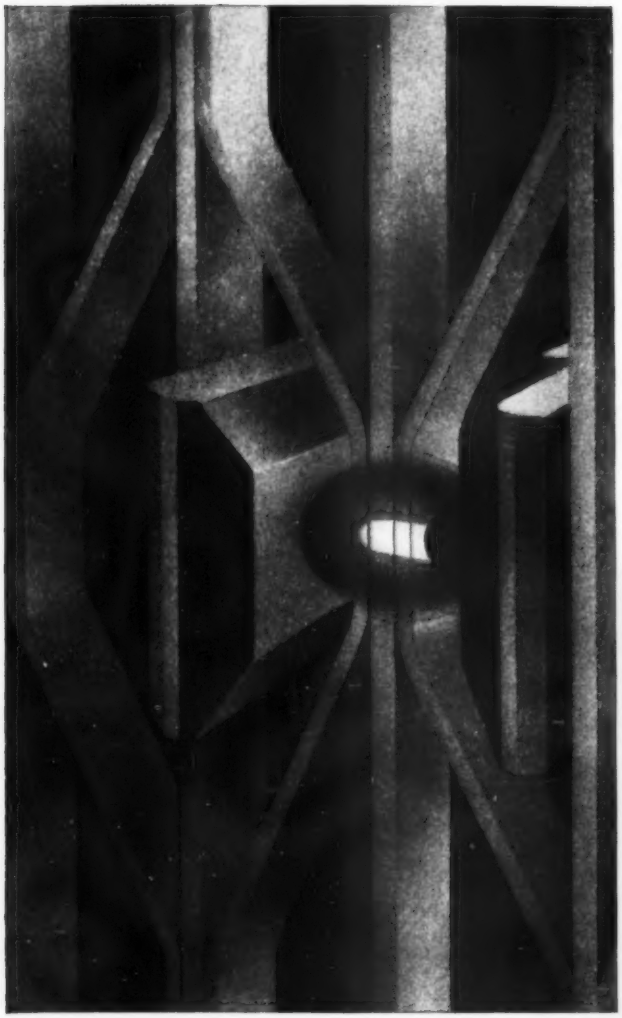

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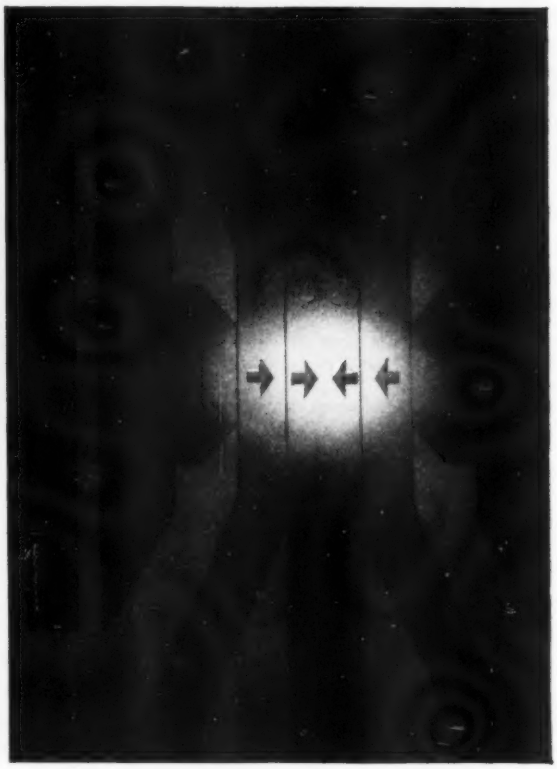

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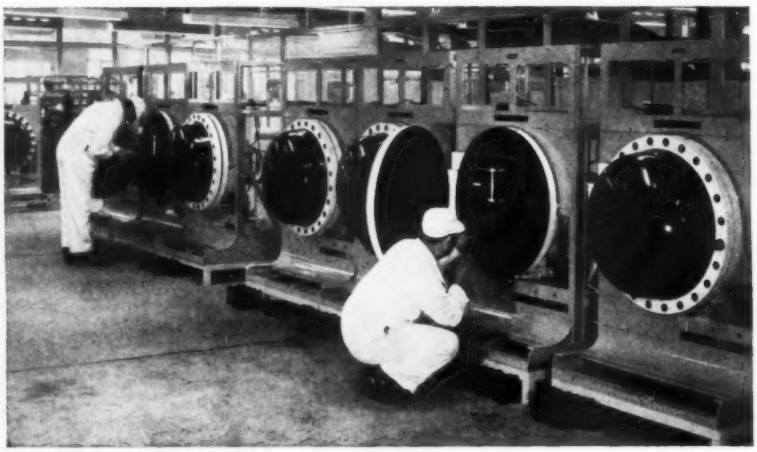

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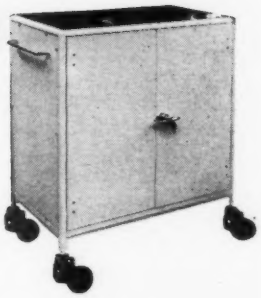

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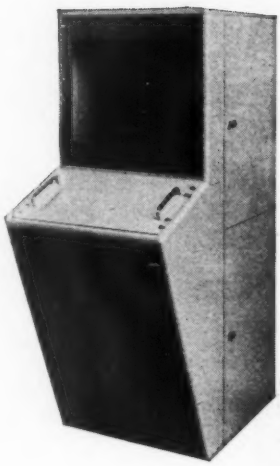

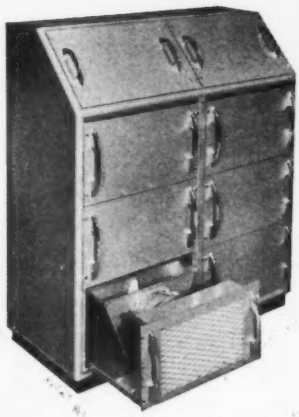

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Algeria: E.G.E.E., Paris (19)
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Belgium: Rogelec, Ghent
Canada: Measurement Engineering Ltd, Arnprior
Denmark: Tage Schouboe, Copenhagen N
Finland: Oy Scienta Ab, Helsinki
France: E.G.E.E., Paris (19)
Germany: Sunvic Regler GMBH Solingen—Ohligs
Holland: J. Th. van Reijsen, Delft
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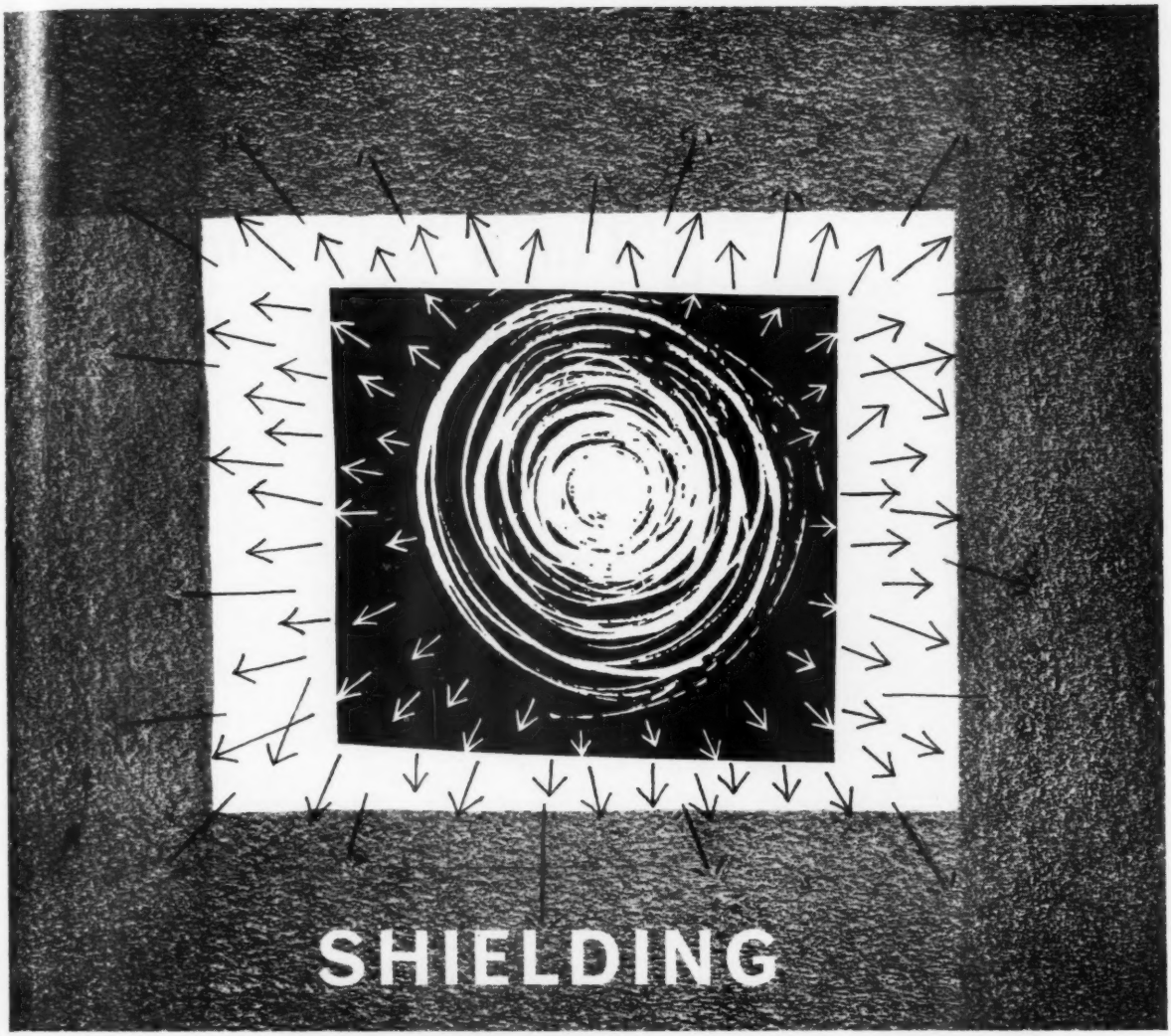


FROM RADIATION

We have a long history in working with lead as well as substantial engineering and metallurgical resources, and will co-operate, from drawing board to installation, on any lead or lead/polythene shielding jobs which are required in these days of nuclear development. We have in general use at our Works comprehensive testing facilities, including gamma-ray radiography, scintillation counting and ultrasonic testing equipment, and will welcome the opportunity of quoting you for any radiation shielding work which you may require.

ASSOCIATED LEAD MANUFACTURERS LIMITED

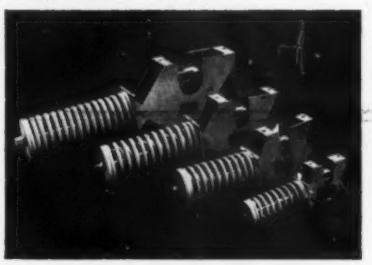
CLEMENTS HOUSE, 14 GRESHAM ST., LONDON, E.C.2 · CRESCENT HOUSE, NEWCASTLE · LEAD WORKS LANE, CHESTER

"I'm a belt and braces man, myself"

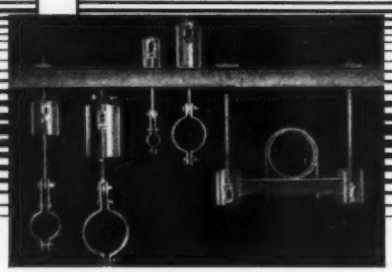
"Because I wear both, my mates reckon I'm a bit of a pessimist! But when it's a matter of essential support I'd rather be safe than sorry. Likewise, I've rigged enough to know that pipework suspended from Gensprings is never going to give any trouble. They use Gensprings on the big nuclear stuff!

This small one just above my head is an M2 Constant Support Hanger. There's a range of sizes to deal with loads from 315 lb. to 97,800 lb. Maximum deviation—if you need it this exact—can now be guaranteed at not more than 2%.

Then there are the Variable Supports for jobs less critical than those needing "Constants", and then again there are Sway Braces for damping out shock and vibration. I'm beginning to sound like the catalogues that Vokes Genspring will be glad to send you!"



Vokes Genspring 'M' Range Constant Support Hangers for supporting pipework and other high temperature equipment such as heat exchangers, furnace walls, condensers, etc. The constant supporting effort is equal to the weight of the pipework irrespective of thermal movements.



The Vokes Genspring range of Variable Supports covers travel ranges of 1½", 3" and 6", and there are 16 sizes in each range, covering loads from 58 lb. to 13,790 lb.

Vokes Genspring Non-Resonant Sway Braces can control all pipework subject to vibration and normal thermal expansion. Eight spring sizes cover loads from 39 lb. to 1,500 lb.

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VG.40

WELL, WHAT IS IT?

(To be fair we should point out that the domed top and fabricated cantilever are part of a test rig. The thing in question begins at the weld below the lettering).

Unless you happened to see, in an earlier advertisement, the cardboard model in which the idea took shape, memory will be no help. This is something quite new.

It is an expansion joint, one of 72 such joints that will take up the expansion of the CO_2 ducting at the Trawsfynydd Atomic Power Station. Internal pressure 265 p.s.i., temperature 420°C.

The convoluted bellows holds the internal pressure; the end thrust—over 1,000,000 lb.—is taken by the inclined, high-tensile steel bars round the periphery; flexing is entirely by elastic straining of these bars. The illustration shows the joint being prepared for the Insuring Authority's acceptance test—1,250 full deflections under full internal pressure and temperature. Compared with previous joints for this kind of work it is lighter, simpler, cheaper. It is the kind of highly original solution to both new and old problems that Richardsons Westgarth engineers can, and frequently do, produce.

RICHARDSONS, WESTGARTH & CO. LTD.

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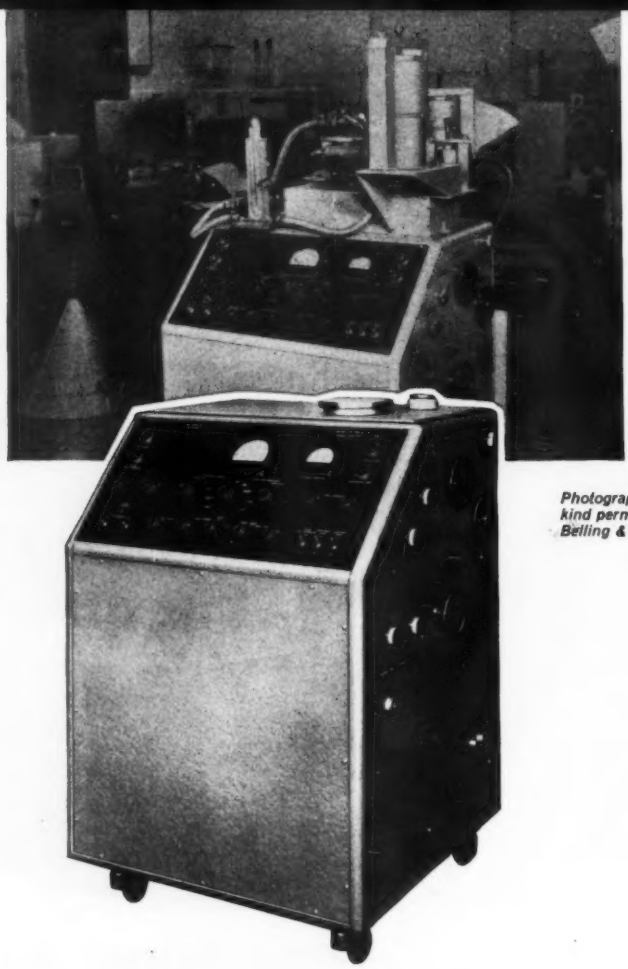
Associated with Atomic Power Constructions Ltd.

RW68

MASS SPECTROMETER LEAK DETECTOR



Photograph by kind permission of Belling & Lee Limited

In this one instrument there is a complete leak detection installation requiring no ancillaries. The instrument can be applied to both evacuated and pressurised components and the rapid response gives a quick turn-round — up to 100 components per hour.

The instrument is completely portable and incorporates a high speed pumping system coupled to the miniature mass spectrometer. Designed specially for leak detection, the mass spectrometer can be used with hydrogen or helium as the probe gas and in addition to meter indication a loudspeaker gives an audible indication of the leak. An ionisation gauge and a pirani gauge are also incorporated, extending the leak detecting range to tens of lusecs. 20th Century's engineers are always willing to discuss new applications of this instrument. Write today for leaflet MS.601 for further information.

- *Precise location of leaks*
- *Audio leak indication*
- *Applicable to vacuum or pressure vessels of any size*
- *Rapid response*
- *Analysis of residual gases*
- *High pumping speed for rapid testing*
- *Leak detection range 10 lusecs–10^{-7} lusecs*
- *Calibrated leak for checking sensitivity*
- *Portable, rugged instrument with fully automatic protection circuits*

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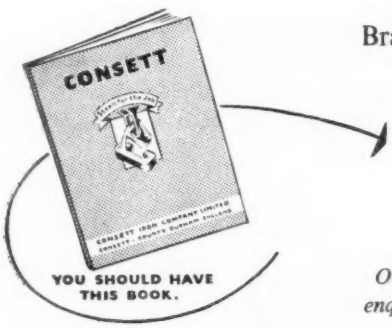
Not only mild steel for everyday use but also the special steels demanded by the Nuclear Age . . . for example we produced the special steel plates for the reactor vessels at Calder Hall, Chapelcross and Bradwell, and we are now supplying plates for the nuclear power station reactor at Latina, Italy.



An interesting booklet "Steels for the Job", just published by us, describes some of our newer products. We shall be delighted to send you a copy.

Our Technical and Research Department will also welcome enquiries from any whose problem is . . . **STEEL**

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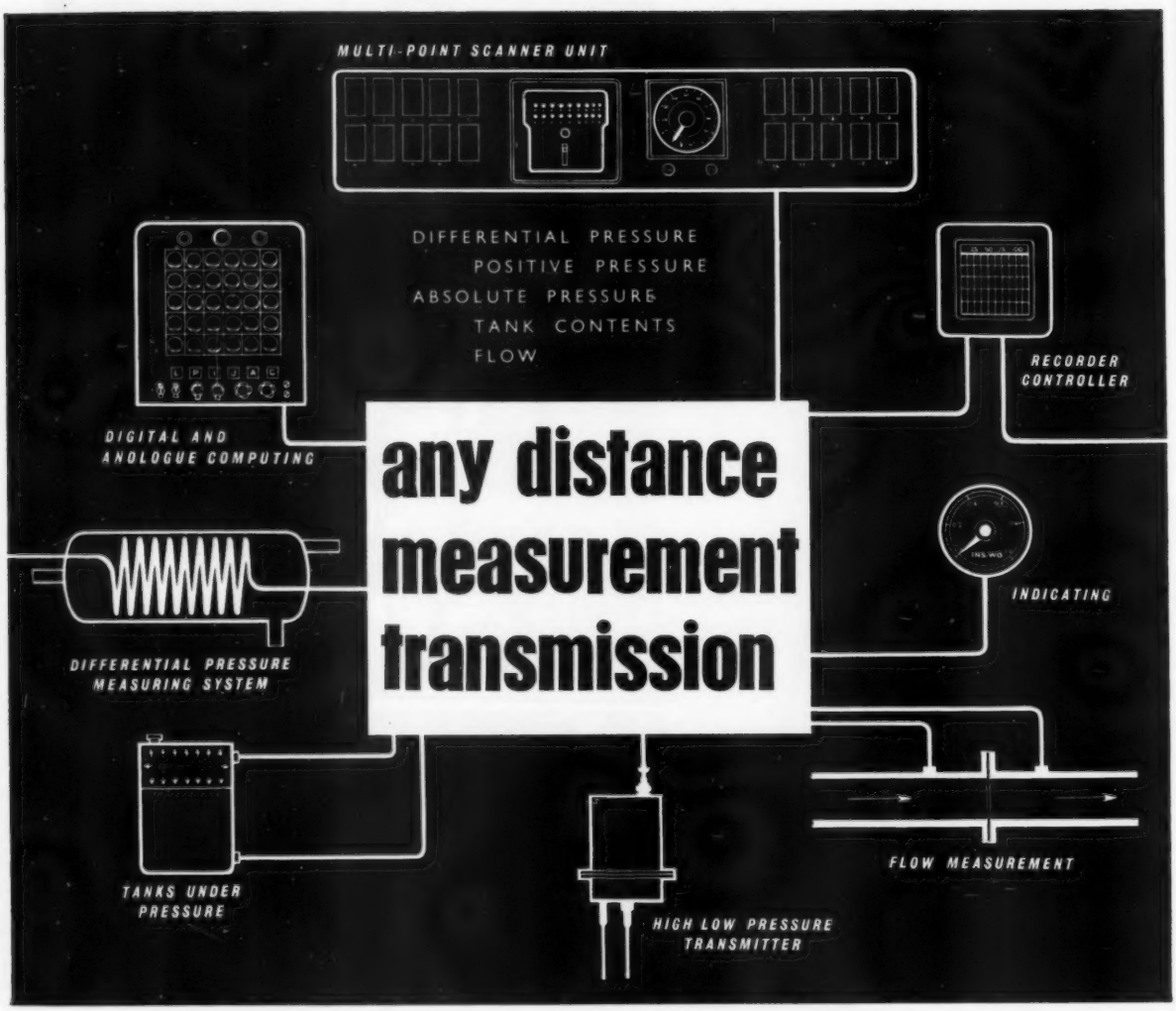

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As specialists in the manufacture of stainless steel products for 30 years, we have exceptional knowledge of the material. Our staff are skilled in the design of equipment in this metal and our work people in its manipulation. You can therefore place your requirements in no better hands.

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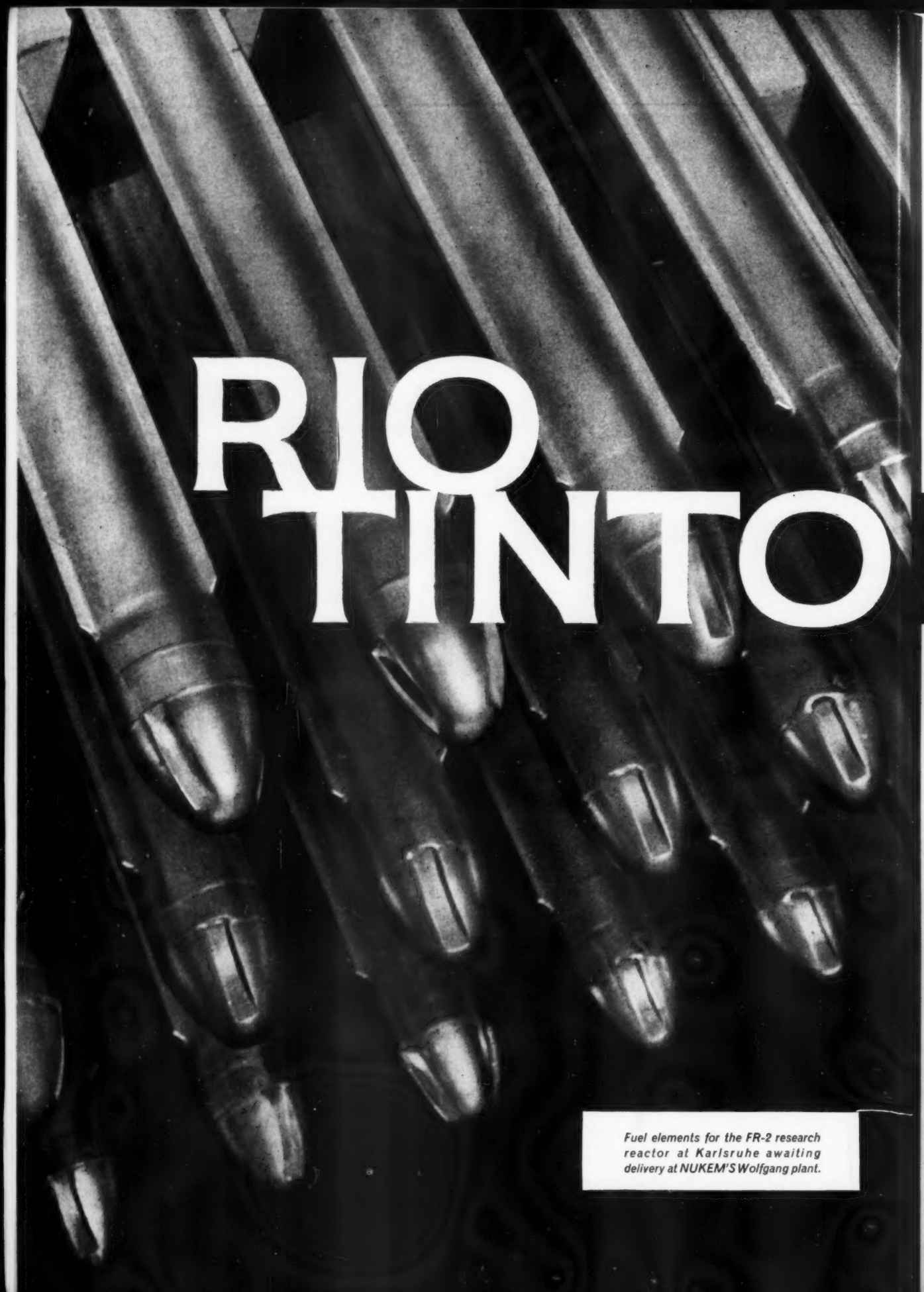
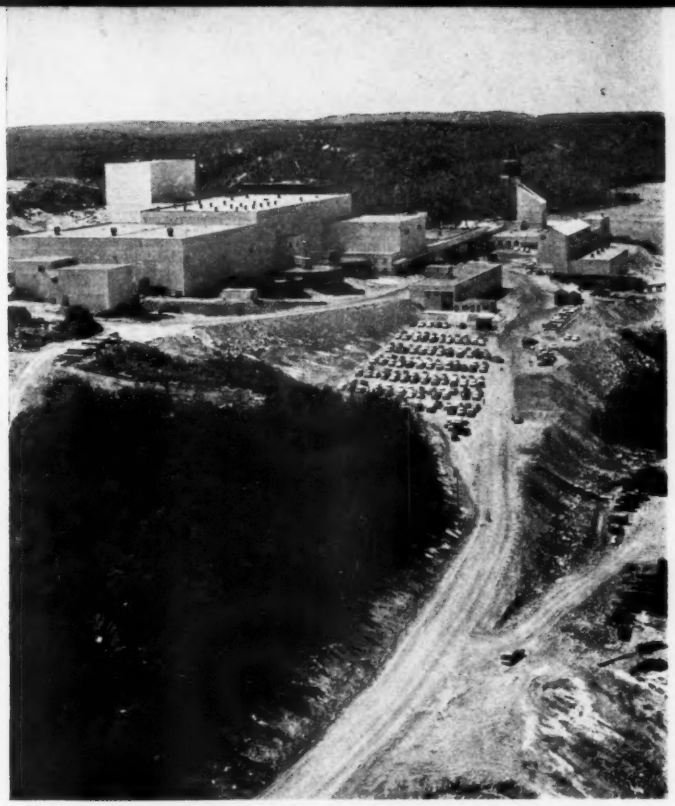


Fuel elements for the FR-2 research reactor at Karlsruhe awaiting delivery at NUKEM'S Wolfgang plant.



The 3,000 ton per day Nordic uranium concentrating plant of Rio Algom Mines Limited, Canada.

ON EUROPE

Rio Tinto has joined forces with the leading German metallurgical group, Deutsche Gold- und Silber-Scheideanstalt vormals Roessler (Degussa), to form NUKEM—Nuklear-Chemie und -Metallurgie Gesellschaft m.b.H.

NUKEM has taken over the research and production programme of the Degussa Nuklear Gruppe, covering a wide range of uranium and thorium processing and fabricating activities related to the nuclear power programmes of a number of countries.

NUKEM is co-operating closely with Rio Tinto's Canadian uranium mining interests and with Rio Tinto Dow Limited, a company specialising in uranium and thorium processing.

Nukem—Nuklear-Chemie und -Metallurgie Gesellschaft m.b.H., Wolfgang bei Hanau (Main)
Rio Tinto Management Services (U.K.) Limited, Barrington House, 59, Gresham Street, London, E.C.2.
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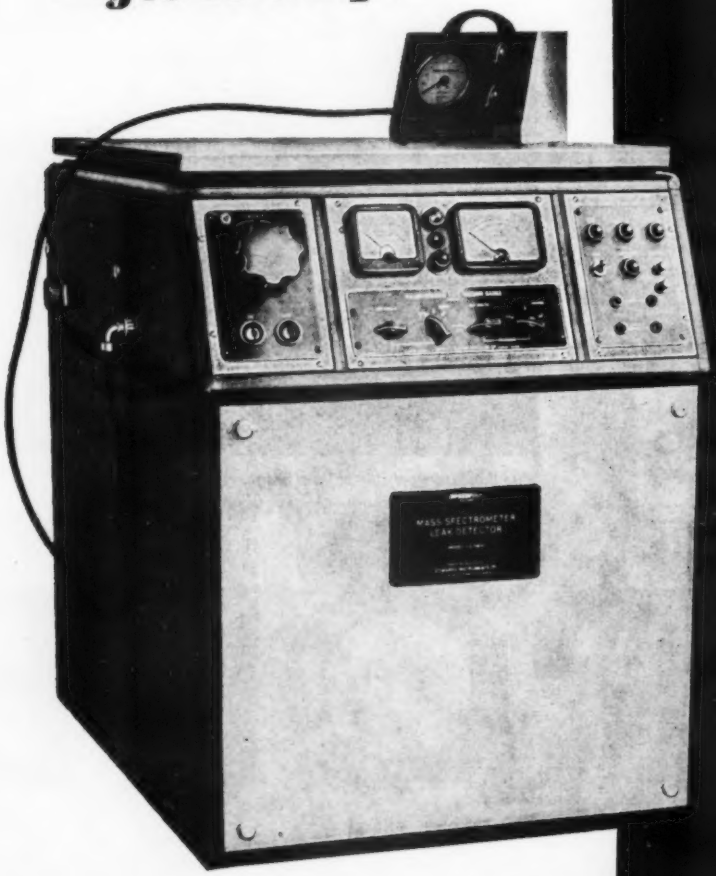
Superbly sensitive —yet so simple!

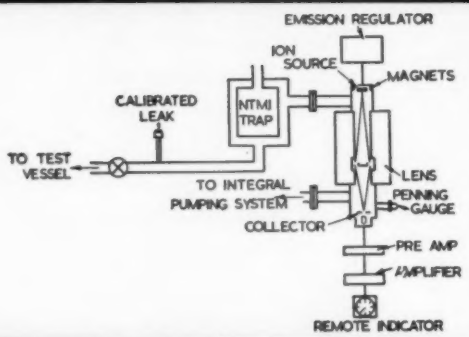


Although no leak detector is sufficiently sensitive to actually count the molecules of searcher gas entering a vacuum system through a leak, an astonishing degree of sensitivity can be obtained with the 'SPEEDIVAC' Mass Spectrometer. This unit although simple to operate has a sensitivity of 5 x 10-10 litre-torr* per second, which is equal to that provided by far more complicated instruments.

A simple focusing system based upon a magnetic lens is employed which is particularly sensitive to hydrogen. The obvious advantages of hydrogen over helium in both availability and price have previously been offset by the hydrogen background common in most vacuum systems. We have incorporated special design features in the LT7 and these, together with the use of a double cold trap system, metal gasket seals and mercury diffusion pumps have overcome this difficulty.

**B.S.2951 : 1958.*

SPEEDIVAC MASS-SPECTROMETER



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Morrisflex 300

FLEXIBLE SHAFT MACHINE

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The M300 is an entirely new machine specially designed for use in the tool room and in all cases where finish is of paramount importance. Optimum speeds are available for cutters in steel or carbide.

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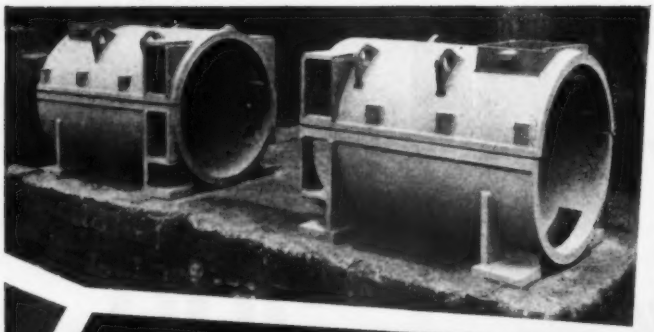

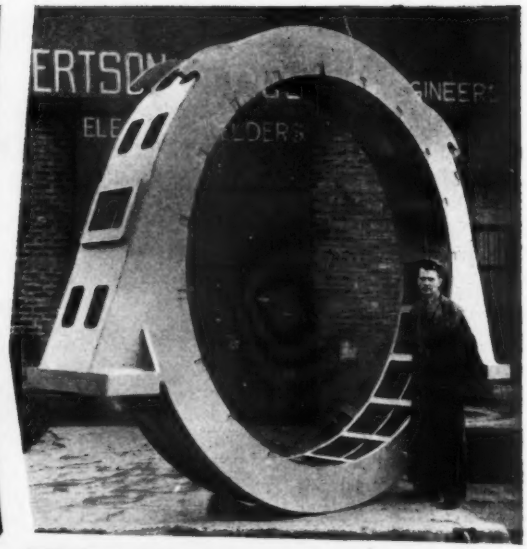

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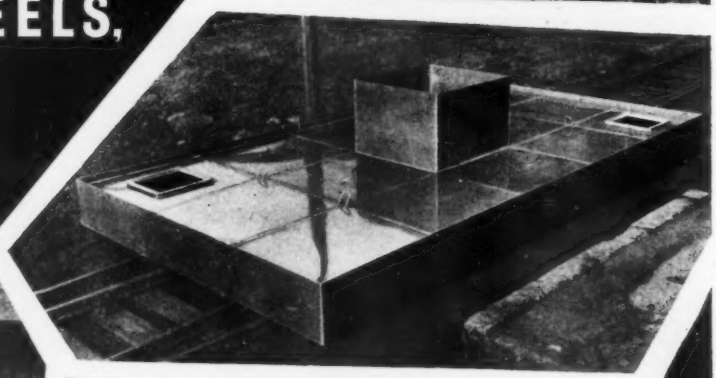

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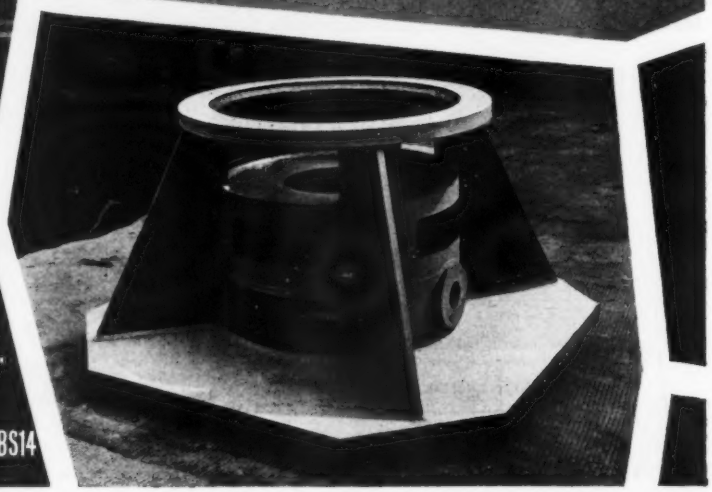

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A Vital contribution to Atomic Power . . .

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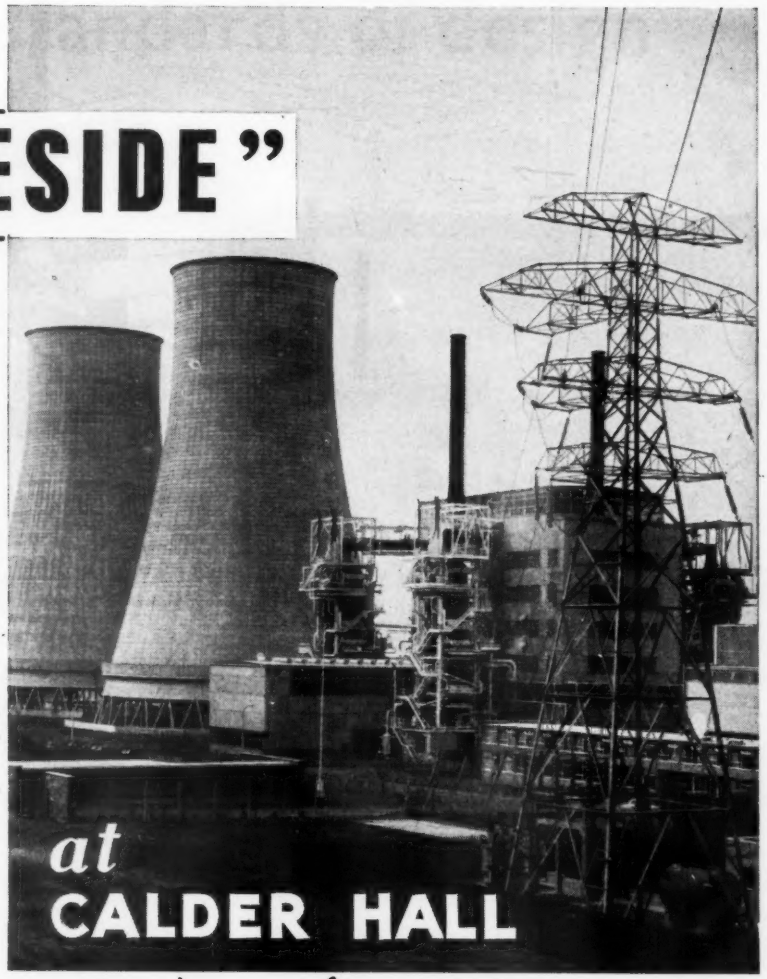

Photo by courtesy U.K. Atomic Energy Authority

With the advancement of Atomic Power, cables must play an important part in the efficiency and reliability in the production of Nuclear Energy. Only the best is good enough and Wandleside Cables are eminently suitable.

WANDLESIDE CABLES *for Nuclear Energy*

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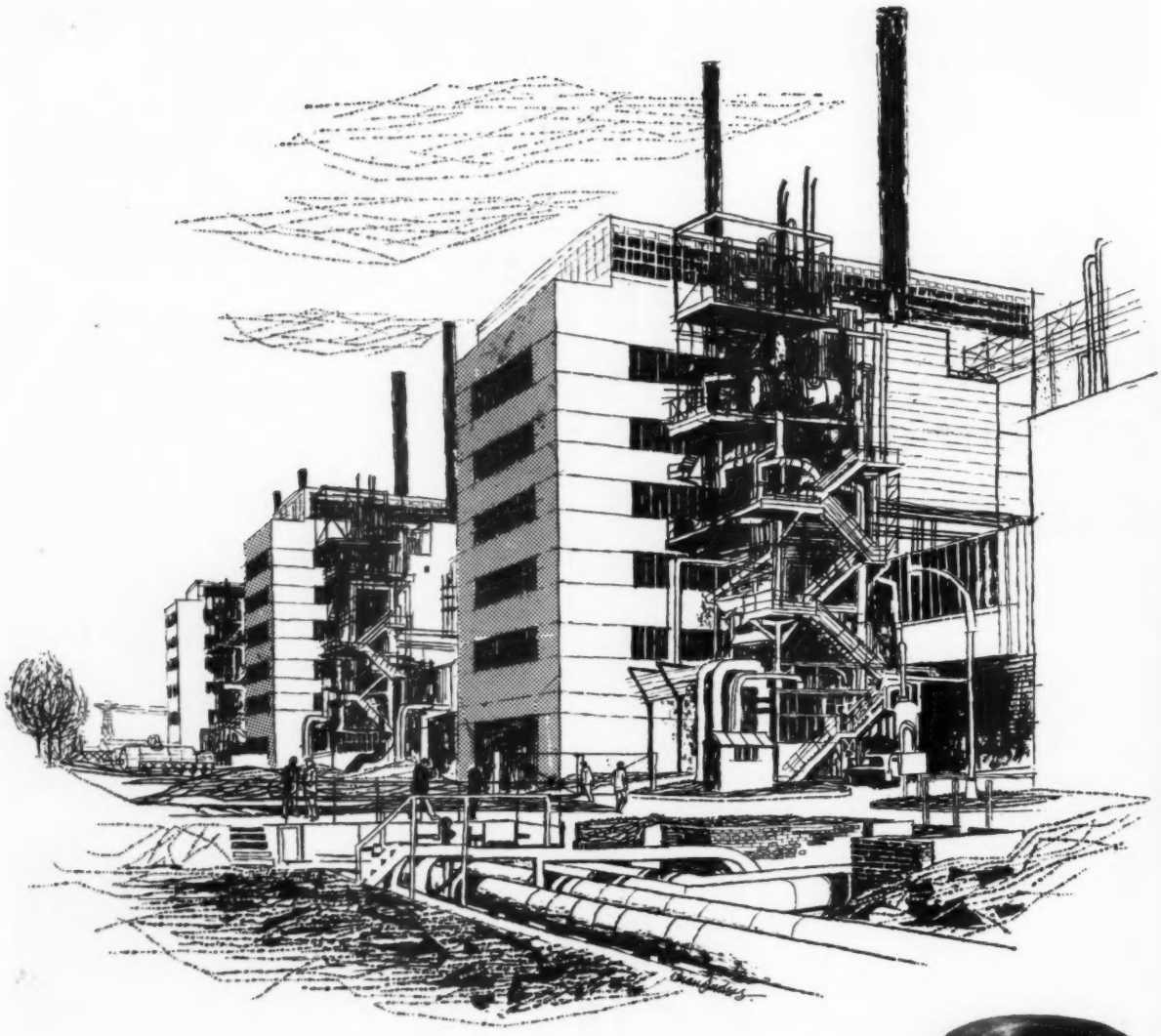
One of FALKS Group *Telephone: VANdyke 7544 (5 lines)* *Telegrams: Wandleside, London*



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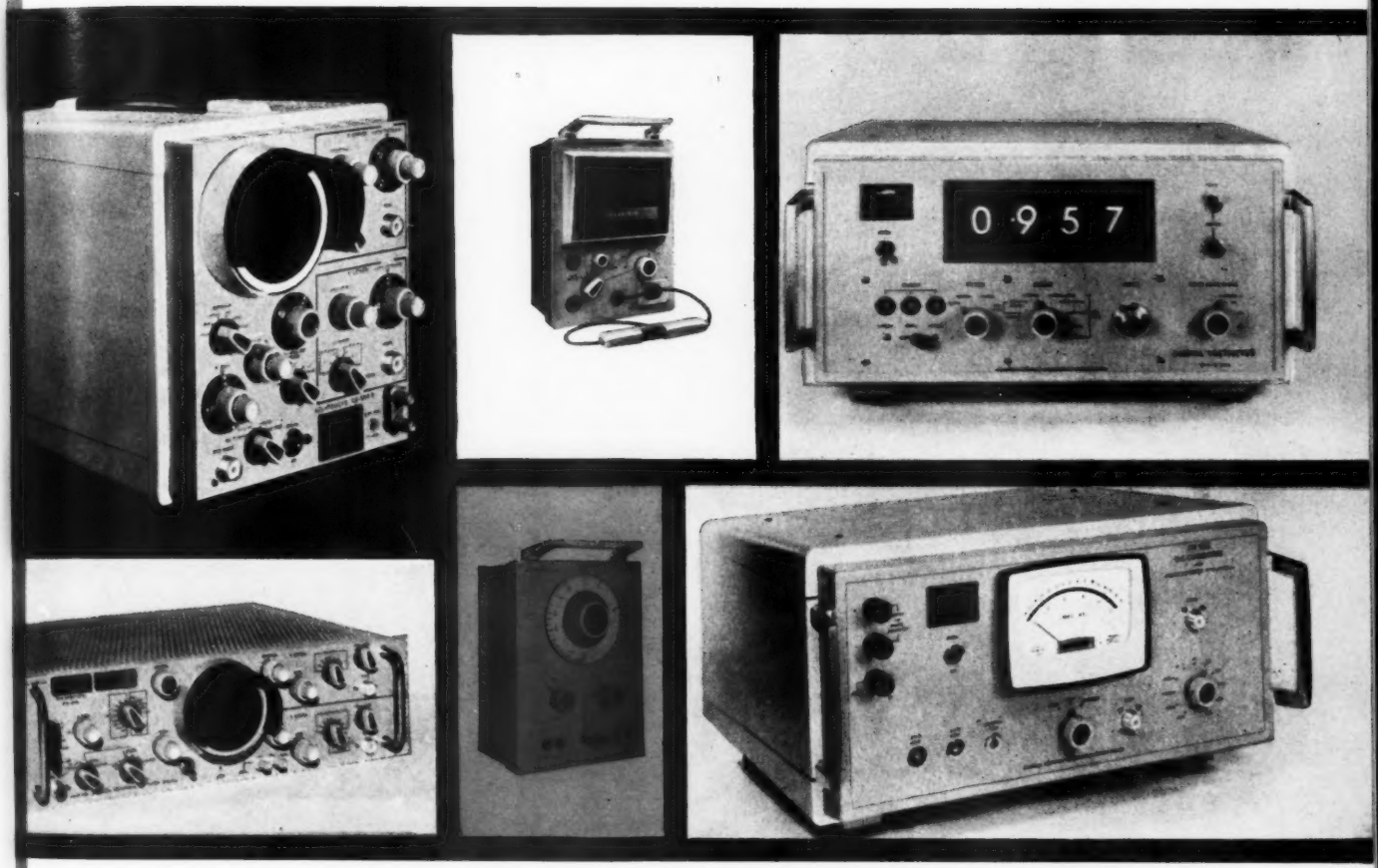
new Solartron instruments set new standards of design



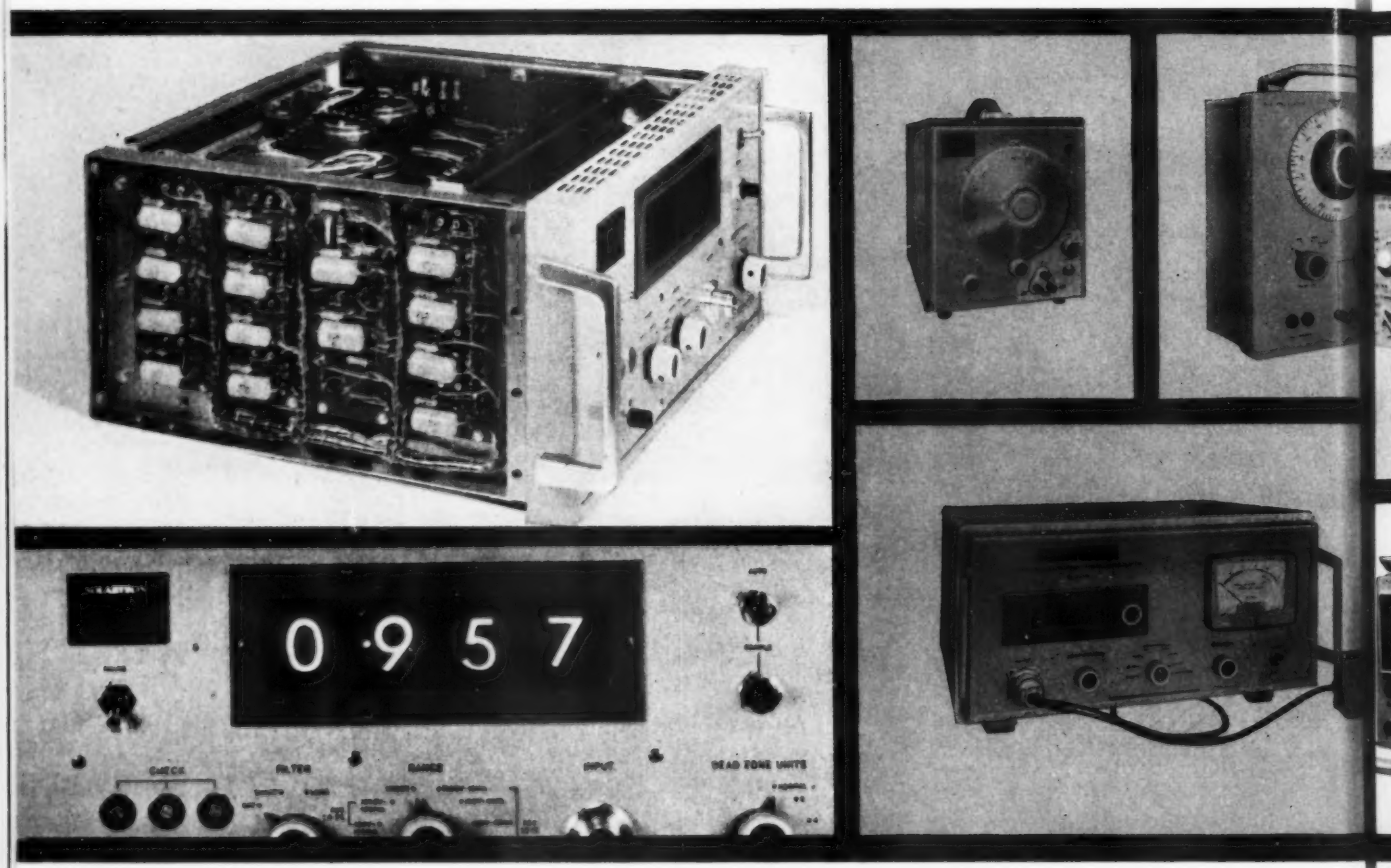
The instruments with the **Solartron new look** mark a big step forward in the science of instrumentation. Precision instruments designed for ease of operation—elegant methods of measurement and display, functional positioning of controls and in a style that has visual appeal.

SOLARTRON

the forward look ——————————→

new ideas new circuit technique

Scientists and Engineers now reap the benefit from the forward thinking and planning in Solartron instrument desi



NEW **Digital Voltmeters**

Decisive and consistent voltage readings by the method which obviates personal errors. A digital display in decimal form with polarity discrimination.

4 Figure DC Digital Voltmeter LM 902.2

100 μV — 1.599 KV in 5 ranges. Accuracy: 0.1% of max. reading on each range. Modes of operation: AUTO for continuous monitoring; SAMPLE for a 'spot' reading. Facilities for print-out and remote display unit.

AC Converter-Voltmeter LM 903

A self contained a.c. voltmeter, designed so that it may be used in conjunction with the LM 902.2 Digital Voltmeter to display rms voltage. 15 mV — 500 V rms (F.S.D. range). Frequency range 20 c/s — 5 Mc/s.

3 Figure DC Digital Voltmeter LM 901

(the first in the series of digital Voltmeters) has an overall range 0.001 V — 109.9 V, and is of compact modular construction suitable for incorporating in any existing equipment.

NEW **Oscillators**

Three new Solartron oscillators—two cover the frequency range 10 c/s — 50 Mc/s and the other, a fully transistorised R-C oscillator, covers 20 c/s — 200 Kc/s.

R-C Oscillator CO 1004

10 c/s — 1 Mc/s, accurate to ±2.5%. 2 phases—0° and 180°. 0 — 20 V r.m.s. D_{TOT} <1% from 20 c/s — 200 Kc/s, <2% outside these limits.

Stabilised Amplitude Signal Generator DO9

350 Kc/s — 50 Mc/s, accurate to ±2%. Additional 50 Kc/s spot frequency. 40 mV — 10 V (pk-pk). Amplitude stability: <2% change in 50 Kc/s—30 Mc/s, <5% in 30 Mc/s — 50 Mc/s.

Portable R-C Oscillator CO 1008

—fully transistorised, operating from internal batteries.
20 c/s — 200 Kc/s, accurate to ±5%. Frequency stability: 0.2% over 8 hour period. Amplitude stability: ±2% over full frequency range.
0-1 V r.m.s. D_{TOT} <0.25% from 100 c/s—200 Kc/s. <1% outside these limits (for battery range 18—14V). Useful battery life 3 months.

SOLARTRON LABORATORY INSTRUMENTS LTD.

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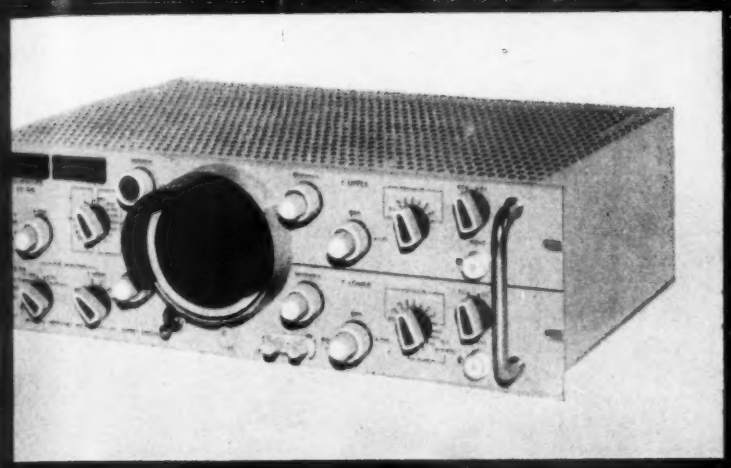
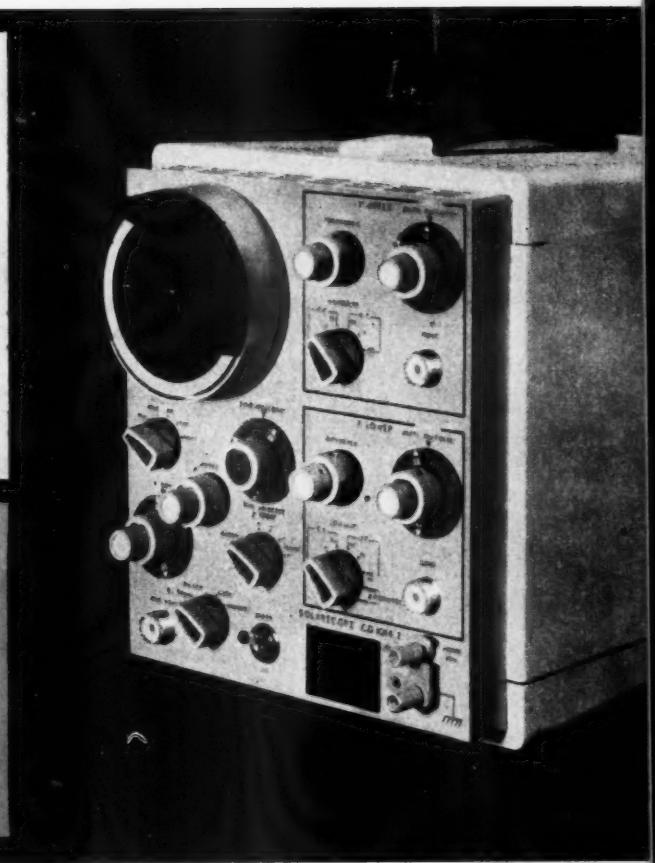
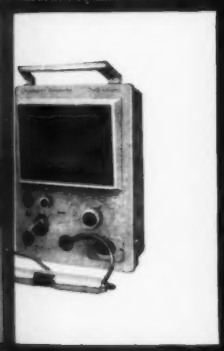
SOLARTRON







Clip-Around Current Meter

Current measurements by a method based on "Hall Effect"—enabling measurements to be made without loading or breaking the circuit.

Clip-Around DC Milliameter AM 1002

—fully transistorised and portable.

0-1 Amp in 5 ranges

0 — 10 mA	±10% accuracy
0 — 30 mA, 0 — 100 mA, 0 — 300 mA, 0 — 1 A	± 5% accuracy

NEW **Direct Reading f-C and L-C Meters**

—to give instant measurement of frequency, capacitance and inductance.

Direct Reading f-C Meter MM 1009

Frequency range:	0 — 100 c/s to 0 — 100 Kc/s (F.S.D.) in 7 ranges.
Accuracy:	±3%. (±5% on the two highest frequency ranges).
Capacitance range:	0 — 1000 pF to 0 — 0.3 μF (F.S.D.) in 6 ranges.
Accuracy:	± 2.5%.

Direct Reading L-C Meter MM 906

Inductance range:	0 — 3 μH to 0 — 300 μH (F.S.D.) in 5 ranges.
Accuracy:	± 3% F.S.D.
Capacitance range:	0 — 3 pF to 0 — 300 pF. (F.S.D.) in 5 ranges.
Accuracy:	± 3% F.S.D.

NEW **Oscilloscopes**

New versatile double-beam oscilloscopes—a portable, accurate measuring instrument (CD 1014.2) weighing only 22 lbs. and a compact rack-mounting version (CD 1016).

Features common to both oscilloscopes

DC — 5 Mc/s Bandwidth Y_1 and Y_2 amplifiers.

Y system

Sensitivity: Y_1 and Y_2 100 mV/cm — 100 V/cm
Y_2 a.c. input 1 mV/cm — 100 mV/cm (at reduced bandwidth).

Measuring accuracy: ± 5%.

Calibration: Square-wave ½ V pk-pk ± 1% at mains frequency.

X system

Writing speeds: 5 cms/μSec — 1 cm/sec (continuously variable).

Measuring accuracy: ± 5% for speeds < 1 cm/μSec.

Synchronisation: AUTO TV Frame, TV Line and Normal switch positions.

'Level' and 'Stability' controls.

Direct access to X amplifier (DC coupled).

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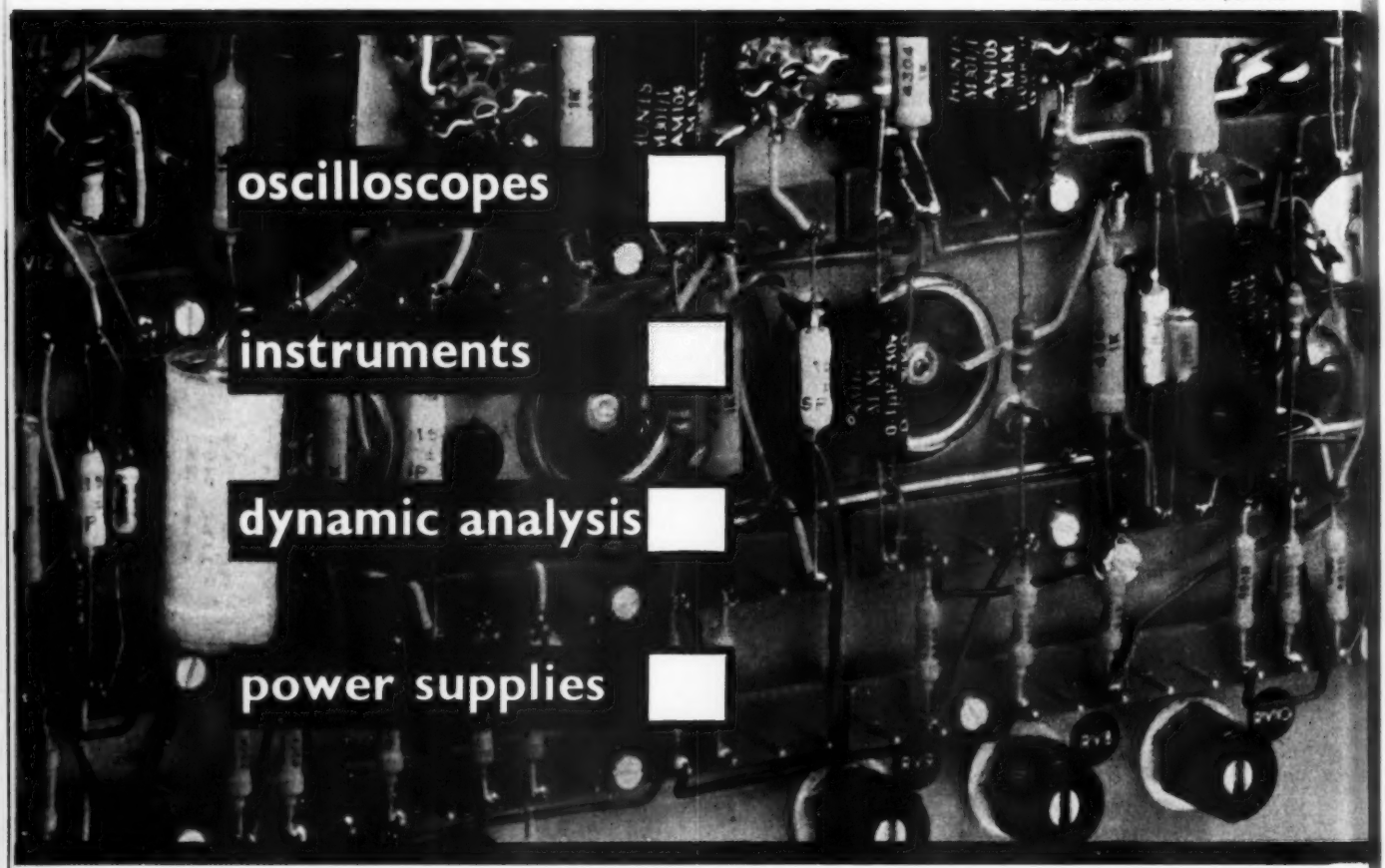

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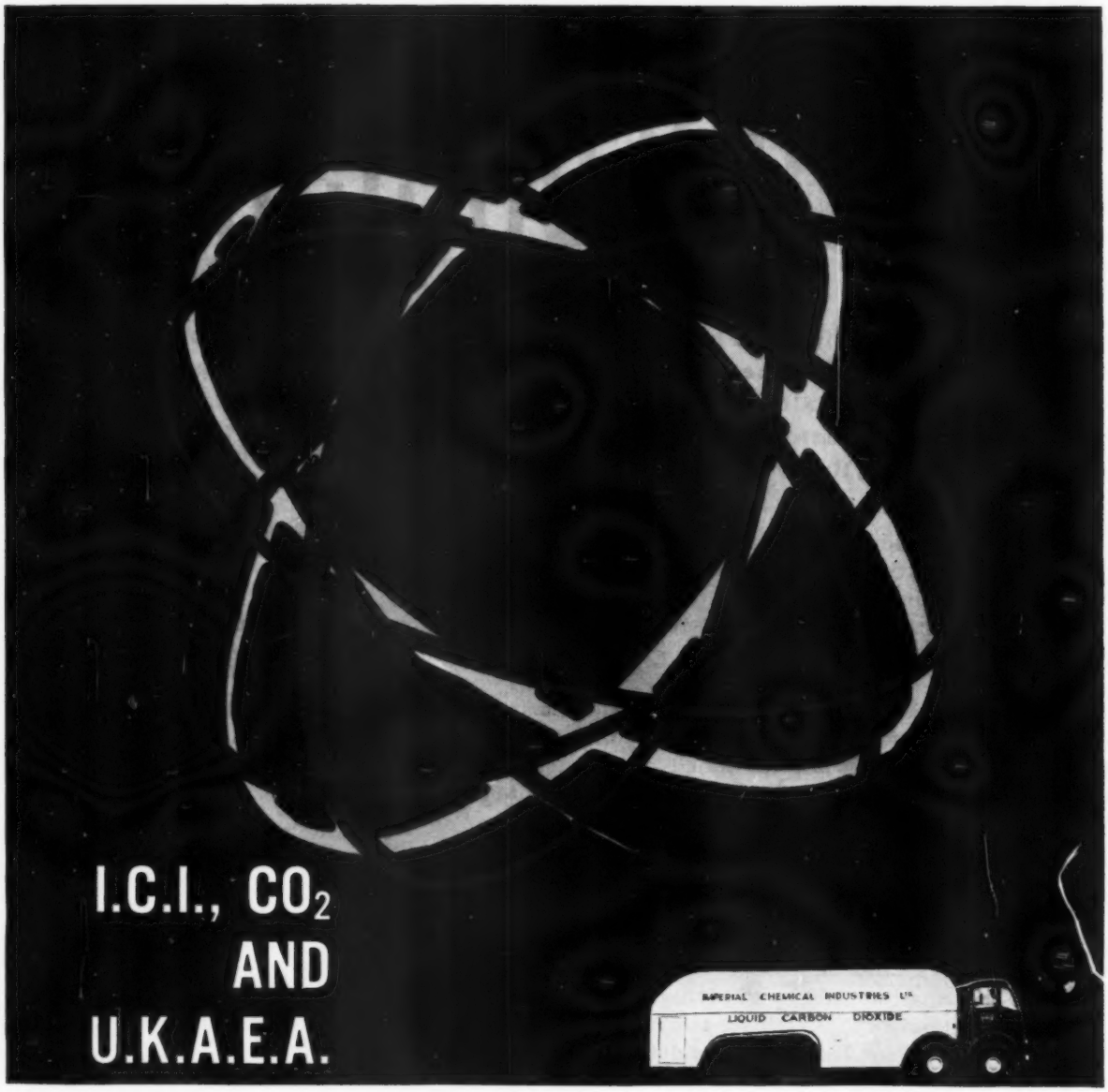

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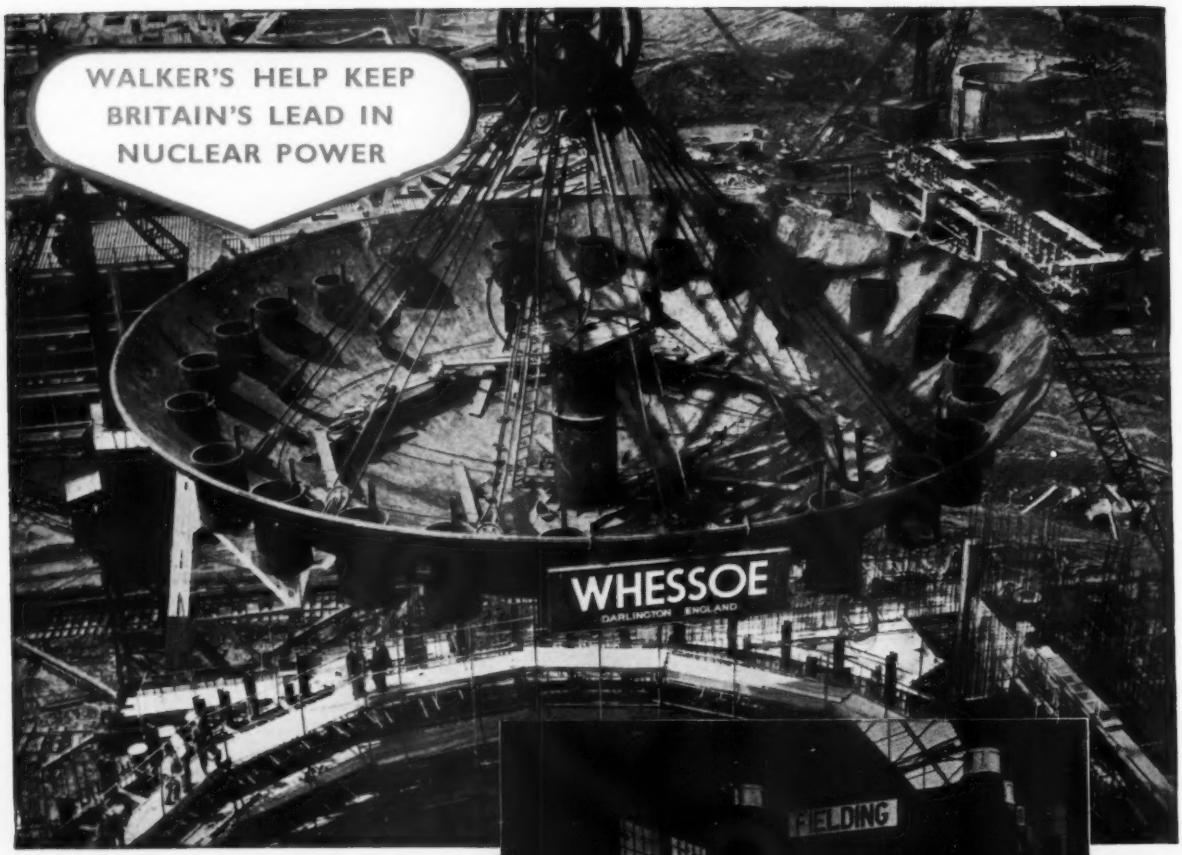

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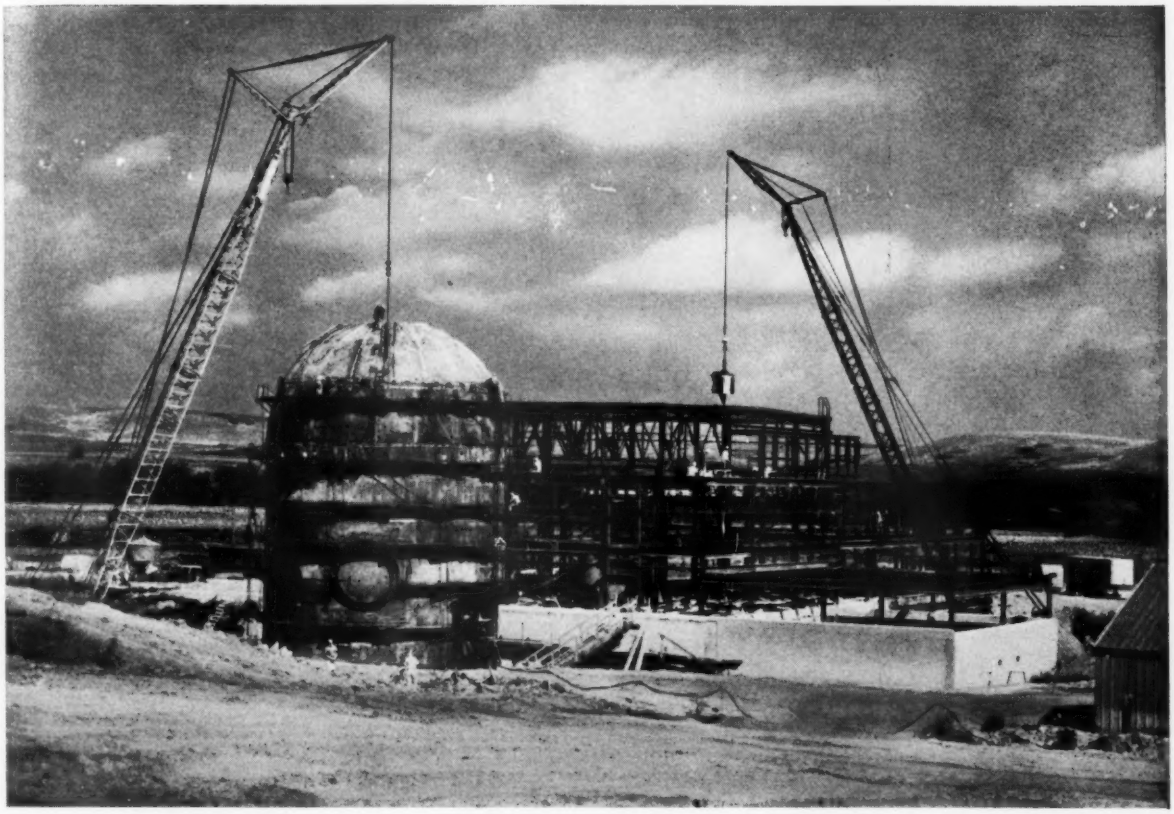

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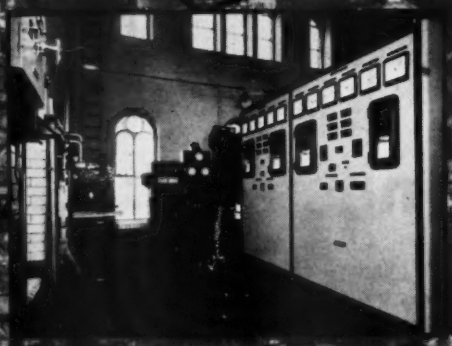
Site of "Pathfinder" plant at Sioux Falls, South Dakota.



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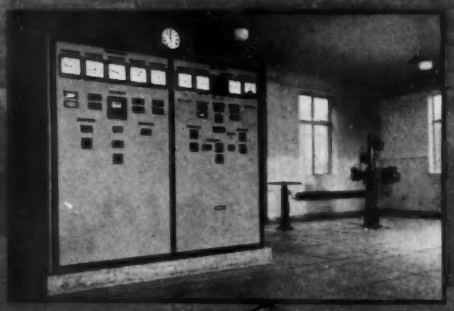

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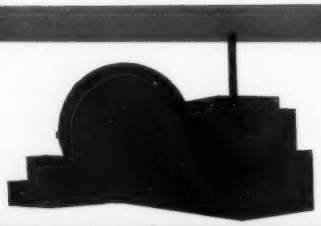

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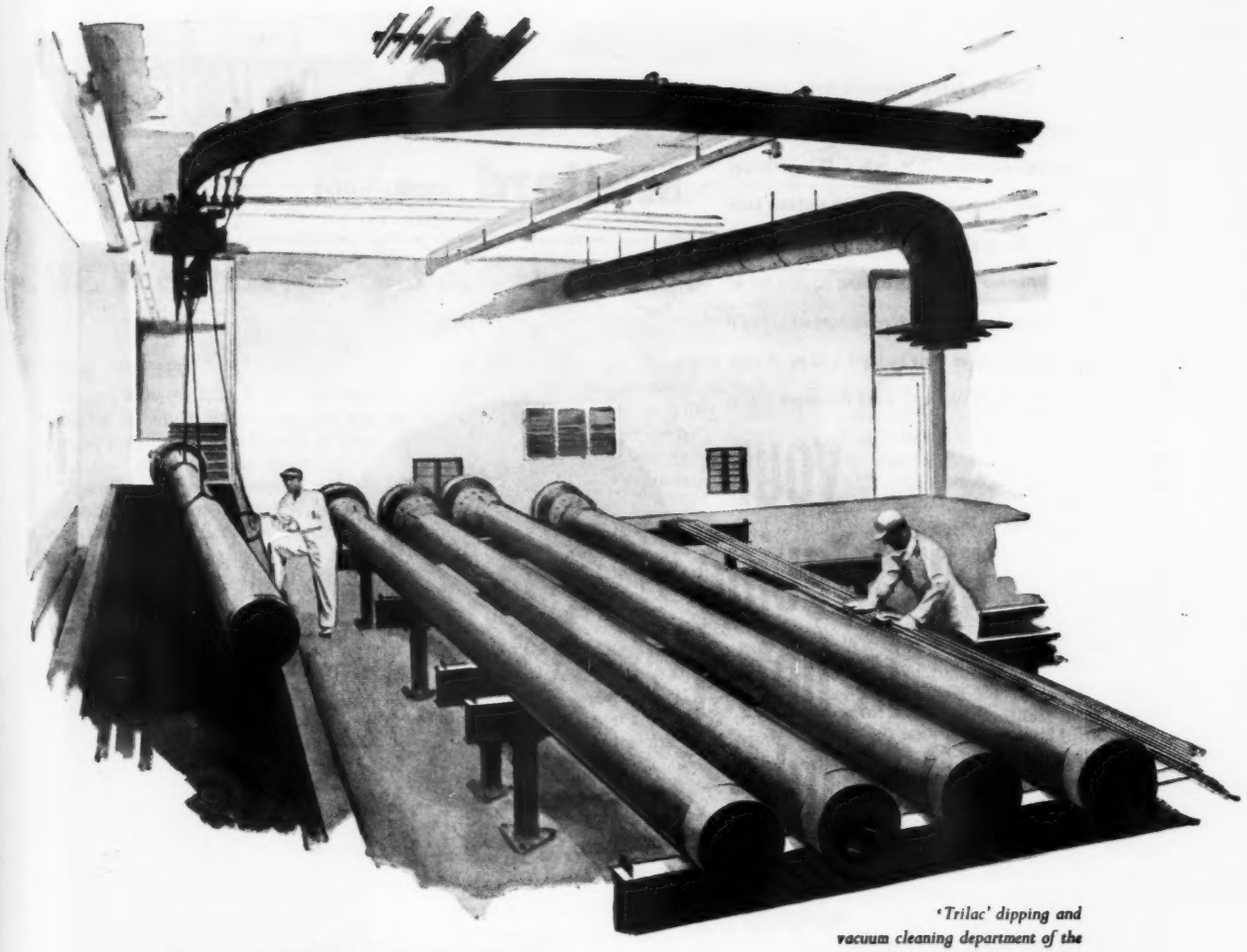

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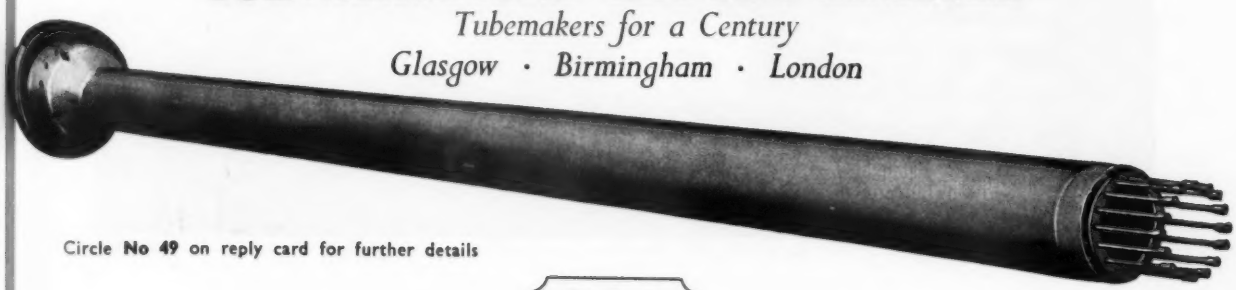

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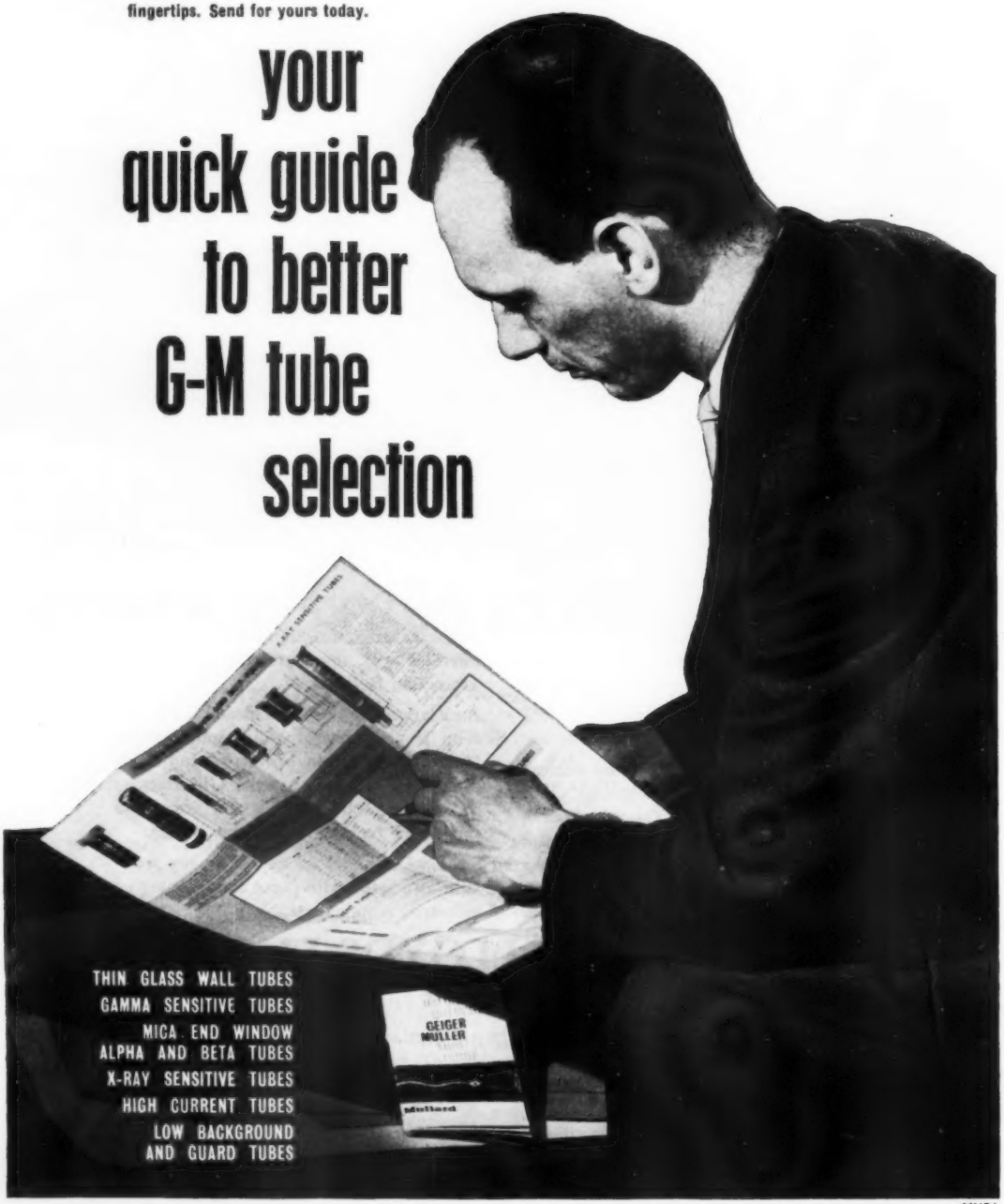

MXR1

Nuclear Power

JANUARY 1961 VOLUME 6 NUMBER 57

VIEWPOINTS *letters to the Editor*

Training reactors

SIR: In reply to Mr H. Montgomery (August issue), it is obvious that the use of large research reactors is outside the scope of the majority of universities and other educational institutions. The small 100 kW reactor is a compromise between the usefulness of the large reactor on the one hand, and the increased safety and simplicity of operation of a small reactor on the other.

The point I raised in my letter (June issue) is that the compromise is taken so far in one direction that the usefulness of the small reactor is seriously open to doubt. I therefore, question whether a reactor, whatever its power, is a generally suitable, flexible and wieldy device for training and research in universities.

I do not doubt that there are special cases as Dr J. Walker mentioned in your September issue, when the low power reactor can be used in particular lines of research. Nevertheless, I feel that, in general, it is not the sort of long-term research tool for widespread installation throughout the world which will generate and stimulate research in new fields by its very presence in universities.

For training undergraduate students, first-hand experience of a reactor is only a small part of a course in reactor technology or reactor physics which the United Kingdom Atomic Energy Authority is quite willing to provide in this country. Demonstration of principles with a reactor is cumbersome and the use of simulated operation can give far more flexibility. On-the-job training after finals is just as valuable and desirable in reactor technology as in any other technology.

Post-graduate training in research is, of course, closely linked with the reactor's research potential.

Following their large-scale efforts to make low power (up to 100 kW) reactors commercially available, the nuclear power industries must now be trying to sell them to whatever buyers they can find throughout the world. This I strongly deprecate because such commercial action in small communities, national or local, may well make appeal on grounds of prestige, technological 'empire' building, and keeping up with the Jones', rather than give a fair idea of the practical limitations and usefulness of low power reactors.

Southampton R. G. SCURLOCK

Scintillation Counter Survey

SIR: By the omission of a separating rule across the last two entries in your October Scintillation Counter Survey, the impression may be given to your readers that Tracerlab Inc. of the USA is an agent for, or the principal of, Plessey Nucleonics Ltd. May I point out that no such connection exists.

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Power cuts

SIR: I have often wondered why there should have been a cut in the nuclear power programme when it appears that it is in the national interest to stimulate development as far as possible.

This shortsighted view makes us burn our one plentiful commodity—coal—and makes us import oil. Surely it would be better to use these two commodities for the chemicals they contain and leave the field clear for electricity generation by nuclear power.

The argument against this is said to be the higher cost of nuclear power—a paper estimate in the main. Against this, one can ask 'Does economics really matter?' If it does, perhaps someone could tell me why, for instance, coal prices rise when demand falls and why a similar situation will arise with some motor cars despite all the preaching about mass production bringing lower prices?

Blackheath, London L. J. CHAPMAN

Merchant ships

SIR: The Ministry of Transport is soon to make its announcement on the choice of reactor plant for a 65,000 ton dwt tanker. That the economics of this will not approach parity with conventional power plant is a foregone conclusion. The question arises, therefore, as to why this is being undertaken at all. Industry has little enough time to spend on nuclear developments which hold some promise, let alone those that are patently abortive from the start.

One thing appears to be certain and this is that a mobile reactor needs enrichment. The higher the enrichment, the more mobile is the reactor. Where one has access to enrichment of unlimited degree, the mobile nuclear power plant can be designed most closely to approach economic parity with conventional plant. Where, however, is such fuel to come from? Resources for enrichment in this country are to meagre and the prospect of utilization of plutonium awaits considerable further development and, in any case, this fissile material looks as though it, too, will be in short supply in the foreseeable future. Apparently, therefore, a programme of nuclear merchant ships will be dependent upon supplies of fuel from the United States or would it be better to concede that nuclear power just does not 'belong' to applications involving small powers any more than the gas turbine belongs to the field of generation of scores, or even hundreds, of thousands of horsepower.

MARIUS (name withheld)

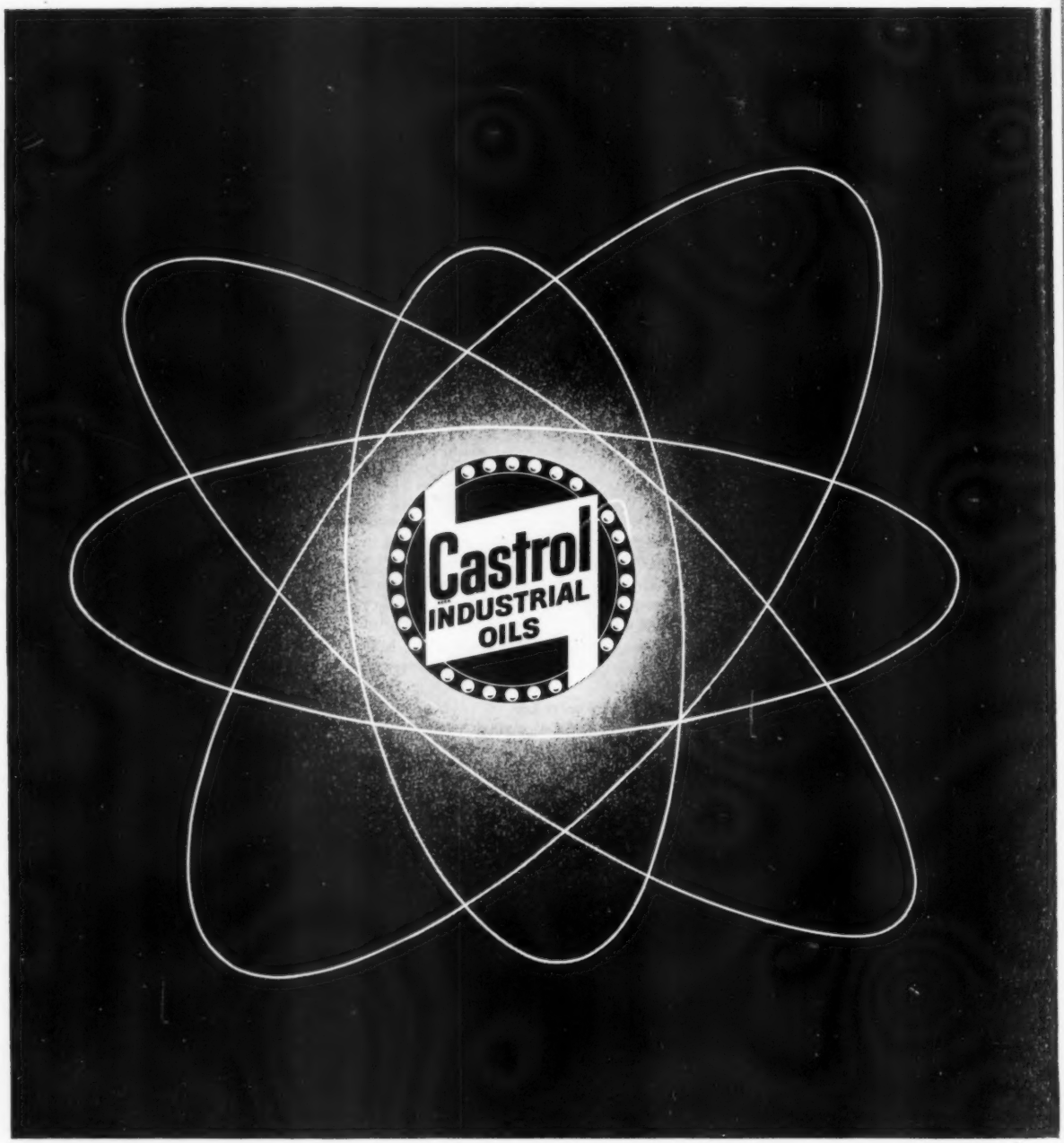
Correction

Due to printing errors, the following amendments should be made in the articles on Beryllium and Beryllia which appeared in the December issue:

Beryllium—L. R. Williams, p 81: Para 1 for '900°C' read '500°C'; for 'density' read 'toxicity'.

Beryllia—J. Williams, p. 84: Para 1 for 'suitable' read 'stable'; for 'independent' read 'in the presence of'; for 'dispersing' read 'dispersion'.

Para 2 for 'this' read 'its'; Para 3 for 'melting' read 'methods'; Para 5 for 'dampening' read 'dependent' and Para 6 for 'Beryllia being' read 'Beryllia has'.



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OPINION

Reactor fortunes

A LOOK AT the world's activities in the nuclear energy field over the past year reveals second thoughts on nuclear power programmes, greater emphasis on the creation of research centres, and a quickening interest in nuclear marine propulsion.

The United Kingdom's programme of construction is still impressive by electrical output standards. As far as experimental concepts are concerned, however, there are many who would like to see a greater variety of operational hardware. In spite of this, the trend towards the high temperature gas cooled reactor system, reflected by the UKAEA's research programme, is being followed elsewhere.

The recent McKinney report, which lays particular emphasis on potential development in Europe and in the less developed countries, supports the CEGB's 'go-slower' policy and recommends that US plans should be focused only on those concepts that offer substantially low-cost power. High cost energy areas, it considers, are disappearing. Euratom, too, sees no immediate need for a large-scale nuclear power programme; rather it is concentrating on the prevention of overlap between national reactor projects, by joining in bilateral and international research projects. Again, in the USSR, reliance is being placed on conventional type stations; and the basis of its nuclear power programme still remains experimental, the long term aim being definite cost competition with thermal stations.

McKinney's 180–230/kW, or 2·5 mills/kWh, by 1970 may seem over optimistic to some, but it could be attained, it is argued, provided that certain primary objectives are taken seriously. More emphasis, for instance, is to be placed on gas-cooled systems but with light-water-moderated concepts still having a place in the scheme. The main effort in the latter direction is the solution of the superheat problem, the extension of fuel life and the lowering of construction costs. Already provision has been made for the inclusion of superheat, either oil-fired or nuclear, in some of the stations under construction — Elk River, Indian Point, Sioux Falls and in Puerto Rico. The pressurized water system is still regarded elsewhere as economical, as indicated by the choice for the Chooz station.

The organic moderated reactor is another active contender in the long range power scene. The US Atomic Energy Commission's latest policy for this system is continued aggressive development; it sees that with calculable improvements, the system has an economic potential. Canada is also interested in it as a suitable system for small stations, but with heavy water as the moderator. In addition, a 30 MW American design-study is being considered by Spain.

The OMR is also competing with light water systems for nuclear ship propulsion. In contrast to the pressurized water designs that have been completed both in Denmark and by Fiat and Ansaldo in Italy, the Hamburg organic scheme is bringing out renewed interest and tenders have been invited. The United Kingdom project involving either a BWR or an OMR is still awaiting a Government decision, one that should come within the next three months.

Considering the interest that is being shown in the OMR type of reactor it should be emphasised that there is only one land-based reactor in actual operation anywhere in the world. Whilst a further three reactors are planned in the USA, two as power station demonstration units and one as an experiment, the need for a land-based facility in Europe is urgent. Perhaps the same thought exists in the minds of the UK Technical Assessment Committee set up to review the five UK ship proposals. It will be interesting to see whether or not such a firm proposal results. If it does, are we to consider it as a commercial development or deal with it on an international basis like the Dragon project?

Many countries throughout the world, while not prepared to commit themselves to a nuclear power programme, are showing an active interest in possessing research facilities, which benefits the exporting countries. America, of course, predominates, with nearly 50 reactors either in operation, under construction or planned. The USSR has exported its 2 MW VVR-S to six countries. Apart from a few special types already sold, the UK industry's entrance into this field is relatively recent. While we can look to private enterprise to push its own sales in this field, it must be realized that government sponsored bodies can play a large part too. American sales overseas have no doubt been aided by a dynamic official attitude. Over the last year, for instance, the USAEC's foreign exhibitions, complete with scientific exhibits, have visited New Delhi, Cairo, Pakistan, and Buenos Aires; with Rio Janeiro, Venezuela and Lima soon to come. That the UKAEA's attitude towards publicity has radically altered cannot be denied, but it must carry out a more vigorous policy overseas, if the American bias is to be counteracted.

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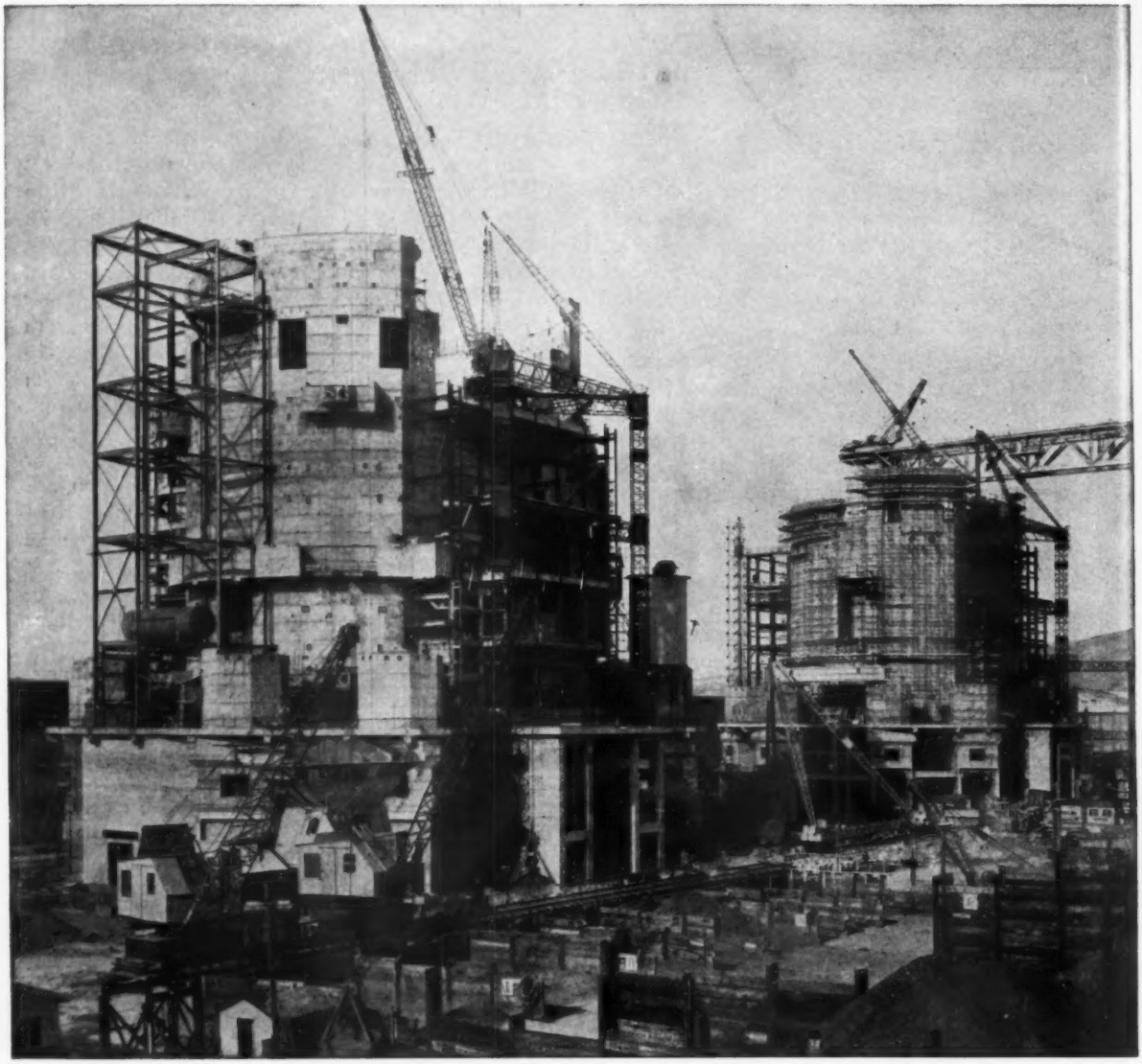

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WORLDVIEW

the month in atomic energy

EUROPE

CEGB asks about Concrete pressure vessels likely for Oldbury and Wylfa

London A nuclear power station with a capacity of up to 800 MW, the largest in Britain, is proposed for Wales. This will be the second Welsh station and may well be the second nuclear power station in Britain to have a concrete pressure vessel. The Central Electricity Generating Board is understood to have let it be known that when tenders are submitted for the proposed station at Oldbury, it would like to see designs for a concrete pressure vessel. Invitations to tender for Oldbury have already been sent to the consortia.

The new 800 MW station is planned for Wylfa Head, Anglesey. The CEGB are to ask the Minister of Power and the local planning authority—Anglesey County Council—for permission to establish this station. It would be commissioned in 1967.

If the station is built, it will be connected to the national grid system at 400,000 volts. This will minimize the number of transmission lines required. Line routes are to be discussed with the local planning authorities and other concerned and an application made to the Minister of Power. If consent is granted, Wylfa will be the CEGB's eighth nuclear power station. The others are: Berkeley (275 MW), Bradwell (300 MW), Hinkley Point (500 MW), Trawsfynydd (500 MW), Dungeness (550 MW), Sizewell (580 MW) and Oldbury (planned). All the stations will be magnox.

The Wylfa announcement came during a spurt of activity by the CEGB, for announcements were also made on the Sizewell contract (for full details, see p 95, this issue) and on the investigations for more south coast sites for stations.

As expected, the CEGB announced its intention to place the Sizewell contract with the English Electric-Babcock and Wilcox-Taylor Woodrow Atomic Power Group (see *Worldview*, October 1959, p. 69). This 580 MW station, the seventh CEGB station, is the largest definitely to be built in the UK. Work is to begin in April 1961 and the station is planned to be in full operation in 1966. A novel feature is a new type of reactor building containing both reactors which, in addition to other improvements, should make the station capable of generating power at a figure well below the national average for Britain and the cheapest in the world from a nuclear power station, says the English Electric Group.

Meanwhile, the CEGB also announced they had decided that investigations had proved that Earnley, Sussex, was technically unsuitable for development as a possible nuclear power station site. However, Hampstead, Isle of Wight, was an excellent site but, because of the amenity value of the West Solent, the CEGB is considering an alternative way of providing more power in southern England at reasonable cost. However, the Board says that with close attention to design and landscaping, a station could be built at Hampstead with little real damage to amenity. But it is deferring a decision to seek consent.

If the Hampstead station does not come about, a conventional station may be built as this and the Earnley site are the only possible ones between Dungeness and Weymouth.

• **United Kingdom** Construction of Nimrod, Harwell's proton-synchrotron, is six months late and the machine will not be completed until 1962.

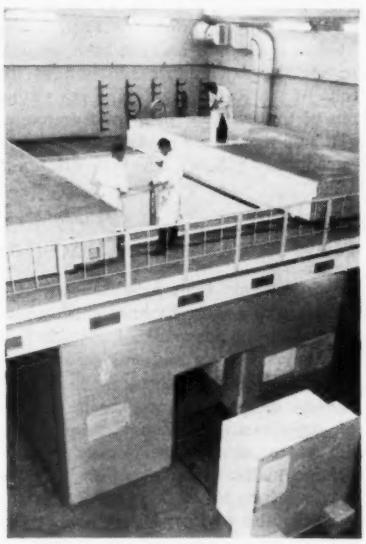
• **OEEC** The Austrian firm, VOEEST of Linz has been awarded a contract to supply four helium containers for the Dragon project.

• **France** Plans are in hand to build several atomic power submarines in the next decade. A recently passed Bill provides £70 million for naval vessels in the next five years, including a nuclear power submarine.

• **Hungary** An 'energy centre' for Eastern bloc countries is to be built in 1962 at Munkacs in Eastern Hungary.

Grenoble gets second reactor

Paris Another research reactor, described as the most powerful of its type in the world, is to be built at the Grenoble research centre. It will have a power capacity of 10 MW and will be a swimming pool type using enriched uranium. Scheduled to go critical in early 1963, the new reactor, called SILOE, is stated to be able to carry out irradiation tests 12 times as rapidly as MELUSINE, the present reactor at the centre.



NORWAY'S NEW REACTOR Looking down at the Norwegian Zero Energy Reactor Assembly, NORA, at Kjeller. This natural uranium pool type reactor is expected to go critical soon and will be used to obtain information on the design and operation of boiling water reactors for marine propulsion

WORK AT DUNGENESS A general view of the reactor/turbine house area at the Kent site of the 550 MW Dungeness station to be built by The Nuclear Power Group. Main activity at the time the picture was taken was concentrated on the perimeter piling shown in the foreground and background (above). The area is to be totally enclosed by piles to form a barrier against water infiltration

Euratom proposes joint research

Strasbourg Britain and Canada should consider undertaking joint research with Euratom. This was the theme of a draft resolution introduced into the European Parliamentary Assembly by a Dutch member, Mr M. A. Janssen.

The Assembly was at the time discussing budget plans for Euratom and also exploring delays in that body's five year research programme. While they provided for $M53 for research and investment by Euratom for 1961, it was pointed out that it had not been possible to see the expenditure required at the time of the Rome Treaty and the setting out of the five year plan for Euratom.

It was then that a draft resolution was introduced calling on the UK and Canada to examine the possibility of undertaking positive common research within the framework of agreements negotiated with Euratom. The Assembly was said to have approved this with reservations but it is expected that some time will elapse before positive action is taken.

Meanwhile, at another meeting in Paris, this time of the Western European Union's Consultative Assembly, Britain was urged to join the Common Market, the Coal and Steel Pool and Euratom. This resolution was adopted by the seven nations making up the Assembly who also said Mr Macmillan should be invited to take part in any eventual 'summit' on the Common Market.

New core raises Dido power level

London A new core has been provided for Harwell's research reactor DIDO, one of the most powerful of its kind in Europe. The improvements to the core will raise DIDO's power still further and are designed to increase the number of experiments that can be loaded into the reactor at one time. A similar modification to the core of another high flux reactor for testing materials, PLUTO, which is also at Harwell, will be carried out this year.

The new DIDO core has increased the reactor power level from 10 MW to 13 MW but the thermal neutron flux remains substantially unchanged. The reactor was first run at low power, using the new core, on October 7. Full power operation began on November 18.

The AEA have three high flux materials testing reactors: DIDO, PLUTO, and DMTR which is at Dounreay. DIDO was the first of these to be commissioned, going into operation at Harwell in 1956.

• **Norway** JEEP, the heavy water natural uranium experimental reactor at Kjeller, has resumed operations after a six month shutdown for installation of a new reactor tank.

• **Euratom** Leading nuclear equipment manufacturers in the Community attended a meeting at Tours recently to discuss means of strengthening ties between industry and Euratom.

• **France** Electricite de France is to take part in the Italian Selni 165 MW PWR project and is taking 8% of the company's capital.

• **W. Germany** The Baden-Wuerttemberg electricity authorities are to set up a company to investigate the building and operating of a nuclear power station.

• **Euratom** The Commission is shortly to publish a monthly 'Transatom Bulletin' in English which will report on Soviet developments in nuclear energy.

Work starts on second Karlsruhe research reactor

Bonn Site work has begun for the second research reactor for the Kernaeaktor Bau- und Batriebsgesellschaft mbH centre at Leopoldschafen/Karlsruhe. The whole installation comprising a 'Siemens-Argonaut reactor', a gas-tight reactor building and ancillary laboratory, will be provided by three firms — Siemens-Schuckertwerke AG, Erlangen und Berlin; Lurgi Gesellschaft fuer Chemotechnik mbH, Frankfurt/Main; and Pintsch Bamag AG, Butzbach/Hessen.

The reactor will have a sustained maximum output of 10 watts thermal and the whole installation is expected to be complete by the autumn of 1961.

UK-Euratom meetings

Brussels Early in 1961, Euratom and UK experts will be meeting at Harwell and Winfrith to discuss the pooling of data in the basic fields of reactor and engineering physics. A communique on the second meeting of the UK/Euratom Continuing Committee for Co-operation, which took place here recently, stated that at the Harwell meeting, particular attention would be paid to measurements.

The possibilty of further co-operation based on UK and Euratom programmes on the AGR, magnox and organic-moderated reactor systems, was also looked into. In addition, as two Euratom engineers had started work at Harwell, the Committee considered further exchanges, including attaching British staff for some months to the BR-2 reactor at Mol.

• **Spain** A four-man delegation visited W. Germany for two weeks and had talks on machinery Spain needs to process its uranium ore.

• **United Kingdom** The Bill to allow the CEGB to use Bradwell and Hinkley Point power stations for radioisotope production was given an unopposed second reading in the House of Commons.

• **W. Germany** A new research institute has been set up at Goettingen University to study uses of isotopes.

Senn reactor output increase proposed

Rome Redesigning of the SENN 150 MW boiling water reactor to increase its electrical output by 50% is underway. The station, which will use uranium oxide fuel, is scheduled for operation in 1963 and after this date SENN (Societa Elettronucleare Nazionale) is to conduct a research and development programme to determine the feasibility of increasing its electrical output.

If results of the review are satisfactory, the Italian company will install an additional 80 MW turbine generator unit to be fed with steam from the reactor. The plant is on the Garigliano River, south of Naples.

Engineers at the General Electric Company's Atomic Power Equipment Department, who are designing the reactor system, say it has been so designed to prevent a 'bottleneck' should the rating be later increased.

GEC graphite pact with Japan

London A long term agreement covering the manufacture in Japan of special types of graphite developed by GEC laboratories in nuclear plant has been signed by the GEC and Nippon Denkyoku Kabushiki Kaisha (Nippon Electrode Company). The agreement is for ten years and is subject to Government approval.

• **Belgium** The Societe Generale Metallurgique de Hoboken reports its uranium plant is producing 600 tons of uranium trioxide annually.

• **W. Germany** The University of Mainz is expected to buy a 10 kW Triga reactor for research work.

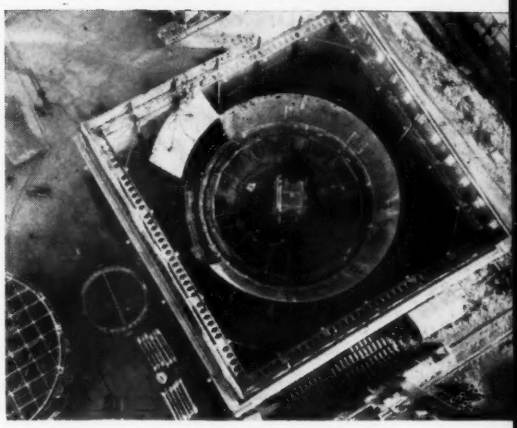
• **Switzerland** Emse Werke AG of Domat/Ems has begun heavy water production. Its plant was established in co-operation with G. Sulzer of Winterthur.

IAEA and ENEA agree

Vienna The IAEA and the European Nuclear Energy Agency have officially signed a protocol regarding the entry into force of their agreement. This dates from September 30, the time of its approval by the IAEA General Council.

The agreement provides for reciprocal representation at meetings, exchange of information and documentation and continuing collaboration between the secretariats of the two Agencies. Special clauses provide for scientific and technical co-operation and the possibility of special services such as the use of personnel or facilities being made available by one Agency to the other.

• **United Kingdom** The greatest possible encouragement should be given to new, more economical, types of nuclear power stations says the Association of Scientific Workers in a policy statement 'A National Fuel and Power Policy'.



TRAWSFYNYDD A bird's-eye view of pressure vessel building No. 1 at this 500 MW station being built by Atomic Power Construction Co. It shows the lowering of the plates prior to welding. Construction work on the station began in June 1959 and commissioning is expected in 1964.

• **IAEA** A manual on the costing of nuclear power is to be issued early this year.

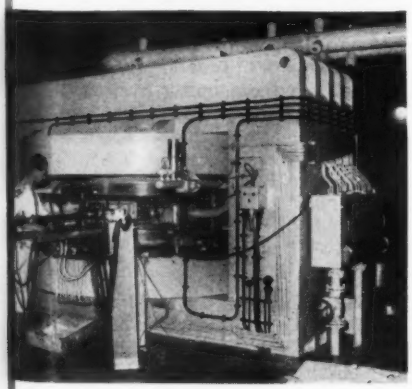
• **Yugoslavia** An agreement on peaceful uses of atomic energy has been signed with Italy.

• **Italy** The Enrico Fermi Nuclear Studies Centre, Milan Polytechnic, has been officially opened.

• **OEEC** The Italian Government has ratified the OEEC convention on civil liability in the nuclear field.

OVERSEAS

E. GERMAN RESEARCH A view of the 25 MeV cyclotron at the German Democratic Republic's Central Institute for Nuclear Physics in Dresden. The Institute, which also has a 2 MW tank type research reactor, is still not complete and when finished will be the country's chief nuclear research establishment



US moves towards 500 MW HTGCR

New York A programme to develop a 300-500 MW high temperature gas-cooled nuclear power station is being undertaken by General Atomic Division of General Dynamics Corporation and General Electric of the USA. The two manufacturers were chosen by seven investor-owned electric utility companies in New York state—Empire State Atomic Development Associates Inc. (ESADA). The objective of ESADA is a plant for which construction would start in 1964 and truly competitive nuclear power—in the 7 mill range—by the late 1960's.

A total of $10,250,000 is to be contributed towards three-year research and development programmes. General Dynamics is carrying out research and development on its HTGR system and at Peach Bottom, Pennsylvania, is building a plant for a group of 53 US utility companies. This would be 300 MW or more and would be designed to produce steam directly at about 1000°F and about 2400 lbs/in². General Atomic Europe, an integrated European company, is also at present engaged in developing high temperature power reactor systems in the 100 MW range, consistent with European technical development and requirements.

General Electric's programme includes the construction of a superheater reactor at Vallecitos, California near its 30 MWt Vallecitos Boiling Water Reactor (VBWR). This new reactor is scheduled for completion in 1962 and will superheat steam either from a separate gas-fired boiler or from the VBWR.

WORLDVIEW

Third UN conference in two years time

New York A third United Nations 'atoms-for-peace' conference may be held in Geneva in the first two weeks of August 1963. The Scientific Advisory Committee to the UN Secretary General recommended this unanimously.

The Committee 'reaffirmed its conviction about the utility of a third conference, stressing it would be of great importance, both for the exchange of scientific information and for taking stock of the developments in the field of peaceful uses of atomic energy'. The Committee also thought the conference should not be held later than 1963.

Dresden control rod fails

Chicago The failure of one of the 80 control rods, which separated from its drive, caused the shutdown of the 180 MW Dresden Nuclear Power Station for 'several weeks'. The break, according to General Electric, who built the reactor, was due to stress corrosion 'cracking of the precipitation hardened grade of stainless steel used in the drive tube'. During the shutdown, a second rod showed some evidence of cracking and as a result, other assemblies were inspected. Shortly after Dresden went critical in October 1959, testing had to be suspended because of difficulties with the control drives.

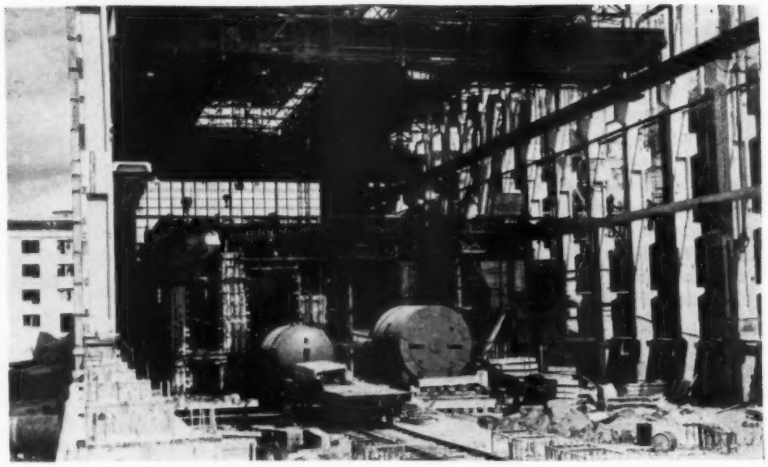
• **Japan** Advanced Technology Laboratories, California, have asked for an export licence for a water-moderated research reactor for Kinki University, Osaka.

• **USA** The Homogeneous Reactor Experiment No. 2 at Oak Ridge National Laboratory has resumed operations after a nine month shutdown for repairs to two small corrosion holes in the reactor core vessel.

Israel denies reactor reports

Washington Reports that Israel is secretly building a natural uranium, graphite-moderated, gas-cooled 'French-type G-1' reactor have been denied by official Israeli sources here and in London. The reports came after US Administration officials had a private meeting with the Joint Congressional Committee on Atomic Energy. Later, Mr John McCone, chairman of the USAEC, when he appeared on a television programme, said that so far 'we have only informal and unofficial information'.

In London, an Israeli official told *Nuclear Power* that the report of a secret reactor was without foundation. Israel only had a 1 MW swimming pool research facility.



SOVIET STATION PROGRESSES Work continues steadily on the 420 MW Novo-Voronezh station near Kursk in central European Russia. Our picture shows the turbo-generator in the main building of the station. The station will have two 210 MW PWR's and is scheduled for 1961 completion

New Canadian use for uranium

Ottawa A new metallurgical process for using uranium as an alloy in strengthening steel has been patented and is now available to the steel industry, the Federal Mines Minister, Mr P. Comtois announced recently.

The method involves the addition of about 1 lb of uranium per ton of steel and the patent is owned by the Crown. The greater strength of the steel and its improved resistance to corrosion is expected to stimulate use of the method in boiler making and tube manufacture.

Meanwhile, a new organization has been formed to investigate possibilities of widening the industrial uses of uranium. Reason behind the foundation of the organization—Canadian Uranium Research Foundation—is the fall in demand for uranium for nuclear uses. Funds for the first five years of operation will be provided by Canadian uranium producers who are seeking new outlets for their ore.

Australian isotope production

Melbourne All the radioisotopes Australia needs can now be produced by HIFAR, the research reactor at Lucas Heights. This was stated by Dr J. P. Baxter, chairman of the AEC, in his annual report. He added that industry in Australia was showing a growing interest in uses of radioisotopes.

The report, the Commission's eighth, said no mining of uranium ore was carried out during the year at Rum Jungle. The treatment plant there operated on stockpiled ore. The report pointed out that the western world's productive capacity of uranium had trebled since 1956 but was unlikely to increase beyond the present level of 42,000 tons of oxide a year until towards 1970.

• **India** Present radioisotope productive capacity is above current demand and the possibility of exports is being investigated.

• **Australia** Installation work has started in Canberra on a tandem electrostatic generator for the National University's Physics Department.

Plutonium Test Reactor critical

Washington Investigations into plutonium recycling by the AEC took a decisive step forward when the Plutonium Recycle Test Reactor (PRTR) at Hanford, Washington, went critical recently. It is the only US reactor designed for this purpose and is undergoing tests during which various patterns of fuel loadings will be tried and the power level gradually increased to its designed 70 MWt. No electricity will be produced.

The aim of the US programme is to develop plutonium fuel elements for use in power reactors. Tests have been carried out in Canada on the NRX reactor and in the UK at Dounreay. The French are also building a reactor, RAPSODIE, for the same purpose.

• **USA** The Babcock & Wilcox Company are the subcontractors for the new 250 MWt AEC high flux Advanced Test Reactor.

• **USSR** The nuclear-powered icebreaker *Lenin* is reported to have travelled through a solid ice pack, 20 ft thick, without difficulty.

This third annual survey covers the main developments in the past year and gives a pointer to likely events in 1961

National programmes in 1960

by SIDNEY L. HOLLANDS, B.Comm.

EUROPE

ALBANIA & BULGARIA

ALBANIAN activities have been mainly confined to membership of the Joint Institute of Nuclear Research at Dubna and the IAEA. Little indication of **Bulgarian** power plans in the next five years has been given. The 2 MW tank type research reactor supplied by the USSR was due to go critical in 1960.

AUSTRIA

THE 5 MWt tank type reactor built by AMF Atomics for the Seibersdorf Research Centre went critical in September. At the dedication ceremony, Mr M. J. Higatsberger, director of the centre, said Austria was Europe's largest exporter of electricity and did not see any immediate need for nuclear power. However, the Austrian National Power Company and other industrial concerns are examining future possibilities.

BELGIUM

AMONG the more important developments during the year was the decision to build a 242 MW PWR plant near the towns of Chooz and Givet in the north of France by the association of French and Belgian utilities known as SENA. Construction will start in 1961 and the plant will come into operation in 1963–64. The BR-2 high flux materials testing reactor went critical in January 1960 and BR-3, a 11·5 MW power prototype PWR, is due for completion soon. Other plans include the construction of a plutonium breeder, to operate by about 1968, by Belgonucléaire, and a 120–160 MW reactor at Dessel, near Mol, by Centrale Nucléaire Belge.

CZECHOSLOVAKIA

THE 25 MeV cyclotron supplied under the bilateral agreement with the USSR went into operation in January 1960. But no news came about the HWGCR 150 MW station being built at Bohunice in Slovakia. This was due to go critical in 1960 and was to be the first of ten nuclear power stations meant to produce 5000 MW by 1970. A second 150 MW station at Banska Bystrica in the Vah Valley is said to be due for completion in 1962. It will be CO_2 cooled and heavy water moderated and was said to be based on a Russian design. Plans are also in hand to build a uranium processing plant and a heavy water production unit.

DENMARK

DANATOM, a group of some 40 firms, completed a comparative design study of a 65,000-ton tanker, known as Alpha, powered by a nuclear, a conventional steam turbine and a diesel plant. The nuclear power plant was a 77 MWt PWR. At the beginning of the year, the 10 MW heavy water Pluto-type test reactor, DR-3, went critical. This will incorporate light water cooling. There is still interest in a heavy water moderated, organic cooled experimental reactor but positive action is still awaited. At Risø, research during the year included studies on gas centrifuge isotope separation.

FINLAND

IN THE power reactor field, no important development took place in 1960. A study group, set up by the Finnish Atomic Energy Commission, the International Atomic Energy Agency and the power company Imatran Voima Oy, made a thorough survey of possibilities of nuclear power in the country's energy production. The survey shows that, taking into account all water power resources, the possibility of using a large base-load thermal or nuclear station with a good load factor will appear around 1970.

Work on the site of the 100 kW Triga Mark II, ordered for the Institute of Technology, started in November at Otaniemi, near Helsinki. The reactor is now expected to be in operation towards the end of 1961. Fuel is supplied by the IAEA. Considerable interest in uranium mining continues among some companies. One of these, Atomienergia Oy, started its mine at Paukkajanvaara, Northern Carelia, in the summer 1960. Daily production is at present about 100 tons of ore.

FRANCE

THERE WAS again some delay in the scheduled completion of the three EDF reactors. Welding difficulties with the reactor vessel for the 63 MW EDF-1 made the completion date the spring of 1961 while the 167 MW EDF-2 is now scheduled for completion in 1962 with EDF-3 (250–320 MW) set for 1964 operation.

A decision was made to start work on EL-4, a 100 MW natural uranium, heavy water moderated gas-cooled reactor. This station is to be situated at Morlaix, Finistere (Brittany). Reports also indicate that the plan to build BRENDA, a 12–17 MW high temperature gas cooled research reactor for studies on gas turbine propulsion, is being shelved. However, the French AEC has still 13 experimental or power prototype reactors in service and four others under construction or on the drawing boards. Of these, the AQUILON research reactor at Saclay (in operation since August 1956) has been enlarged and improved to facilitate lattice studies for EL-4.

Emphasis was placed on military activities but nevertheless the civil programme continued on towards its objective of 1000 MW in 1965–66. By

FRANCE A general view of Saclay, the French CEA's largest nuclear research centre

1975, according to the French Atomic Energy Commission, 25% of the country's electricity will come from nuclear plants.

To cope with this and to treat irradiated fuel elements from the power reactors under construction, a second plutonium extraction plant will be built at Cap de la Hague, near Cherbourg on the Normandy peninsula. Construction is set to start early in 1961 but the capacity has not yet been finalized. Work continued on the Pierrelatte diffusion plant north of Marcoule which will have a capacity of 350 tons per year and come into operation in 1965.

France is now the leading European producer of uranium, having four plants turning out a concentrate containing 60% uranium which is supplied to two plants whose production in 1959-60 was 700 tons, and is expected to be 1200 tons in 1961. For 1962, production is estimated at 1500 tons and the French AEC's annual report points out that this can be increased considerably—if required.

The new 4000 acre research centre at Cadarache progressed steadily and the 30 MWt pile PEGASE is being built there to test fuel elements for EDF stations. A critical assembly, PEGGY, will serve as a test assembly for the eight independent PEGASE loops. The centre will also have the 10 MWt fast neutron, sodium cooled breeder reactor, RAPSODIE. Criticality is scheduled for 1963.

In addition to its own programme, EDF is concerned in the syndicate to build a 242 MW PWR plant near Chooz and has offered to co-operate with Germany on a demonstration power project on an information and operating exchange basis.

Generally, the fuel situation is dominated by oil and gas and nuclear power efforts are looked upon as long term insurance. However, over the last 15 years, the French nuclear industry has grown rapidly. It has close links with the French AEC, the relationship being compared with relay runners. At the point where development risks are negligible, the state hands over to industry which then has the task of launching the process or technique on the home market and overseas, if possible. This unwavering policy has made French industry a force in world markets.

GERMAN FEDERAL REPUBLIC

THE SUDDEN storm over the gas centrifuge method for isotope separation tended to detract from other significant progress. Work was started on the 15 MW AVR 'pebble bed' prototype by the BBC/Krupp group. It will be built at Julich, near the Belgian border. AVR is an association of 14 municipal utilities and the plant may be a prototype for a later 100 MW station. The government is contributing towards the cost.

The Kahl reactor, a 15 MW BWR, went critical in November and after tests, will be brought up to its full capacity, probably before the summer of 1961.

Despite these events and the call for tenders for the country's first nuclear ships by the GKSS, a Hamburg non-profit association formed by 33 shipbuilding and industrial firms, there is still a general 'wait-and-see' attitude. This has been brought about by a combination of events including lower fuel prices, oil pipelines from European ports an the basic lack of a firm national programme. However, the AKS project for a 150 OMR at Baden-Wurtemberg is still being considered and may well come under the US-Euratom programme; a similar situation exists with the BEWAG project at Wannsee, Berlin, though only preliminary designs for this 160–175 MW station have been submitted. Other possibilities are a 50 MW multi-purpose heavy water moderated reactor by Deutsche Gesellschaft fur Atomenergie (Munich); a 50 MW gas cooled reactor by AVR and a 100–150 MW high temperature gas cooled reactor by SKW, an association of six electrical utilities in N. Germany.

The main outlines of the future programme are given in the 1961 budget of 186 million D-marks, including a possible pointer to future policy in the statement which accompanied its presentation. This said that the government should not only finance design but also construction work—a departure from normal practice.

Of the research projects, specific mention is made of a 5–20 MW high temperature reactor; an advanced gas cooled reactor, a 25–30 MW OMR; a 25 MW BWR with nuclear superheat and a mobile 5–10 MW power plant. Basically, the government's programme is aimed at developing small to medium power plants in anticipation of a future export market.

Research work includes a plan by Degussa and Freidrich Uhde Corporation to build a 10 ton/year test plant for heavy water production. It will incorporate a process which makes use of water-hydrogen exchange. Work on the gas centrifuge is now classified.

GERMAN DEMOCRATIC REPUBLIC

CONSTRUCTION work on the first phase of the 70 MW PWR station at Rheinsterg continued according to plan, says a report from the Ministry for Atomic Research and Atomic Techniques. Preliminary work on the project to build a second phase improved reactor of the same type was carried out in the Scientific/Technological Office for Reactor Construction, Berlin. (The first reactor is due to go critical in 1962.)

Work continued on the Central Institute for Nuclear Physics, Rossendorf/Berlin. At the beginning of 1960, the Radiochemical laboratory building was completed and in the middle

of the year, the Nuclear Physics building was handed over. Preparatory studies leading to the construction of a second (zero energy) research reactor for exponential experiments, including determination of lattice parameters, were also carried out. The Central Institute was also the venue in June of an international symposium on the operation and utilization of research reactors. Most of the members of the Dubna Institute took part.

Development and production of radiation measuring instruments as well as apparatus for use in nuclear physics was expanded by VEB Vakutonik, Dresden. At the VEB Transfornen and Roentgen factory, development of a 2 MeV Van de Graaff accelerator was completed and mass production started.

Isotope output

Production of isotopes in the 2 MW research reactor began at the end of 1958. At present, the Central Institute is in a position to deliver about 70% of all types of isotopes and preparations offered on the world market. Considerable emphasis was given to developing applications of radioisotopes during 1960 and in 1961 a sharp increase in the number of users of instruments designed to use radiation is expected. Two exhibitions on uses of radioisotopes were held during the year.

(The Republic's nuclear programme aims at 3000 MW by 1970 and plans have been mooted for a 100 MW station near Lake Malchin to be completed before 1965. Nuclear propulsion is receiving attention at the Warnow shipyard on the Baltic.)

HUNGARY

EARLY in the year an agreement with the USSR for co-operation in the design of experimental and power reactors was announced. Under this, joint work on the use of isotopes, exchange of designs and co-operation in the design and manufacture of instruments will be undertaken. A second research reactor is likely to be built at the Institute of Nuclear Research at Debrecen but there has been no news of a 200 MW reactor on which work was to have begun in 1959 for completion by 1963-64.

ITALY

ACTIVE work went on during the year, reaching one peak with the signing of a contract for a joint industry-government project for a 30 MWt OMR. This was between the National Committee for Nuclear Research (CNRN) and Agip Nucleare. The reactor will use fuel elements similar to the US Organic Moderated Reactor Experiment (OMRE) — highly enriched uranium oxide with stainless steel cladding. The uranium will be supplied by the USA via Euratom.

In July, the Export Import Bank announced it had agreed to lend US $M34 towards the $M64 cost of the 165 MW PWR Selni plant to be built in Northern Italy. The money will finance purchases of US equipment and services with repayment over a 15½ year period, starting in 1964, the year the reactor is expected to be completed.

The same month saw the enactment of a bill under which a National Committee on Nuclear Energy (CNEN) succeeded CNRN. The bill also provided for financing to the extent of £M40 over the next four years for the home nuclear programme. Still to be solved, however, is the problem of nuclear liability and public *v* private ownership of nuclear facilities.

In the marine propulsion field, Fiat, in collaboration with Ansaldo, submitted a design for a 68,000 ton tanker propelled by a PWR with a power of 74 MWt, to Euratom. Fiat has a licence agreement with Westinghouse of the USA on water moderated reactors.

Among other projects being considered is one by Agip Nucleare in North Italy for a 150 MW PWR. Vitro Engineering of the US undertook the preliminary engineering and design study. Persistent unconfirmed reports say that another natural uranium, graphite moderated reactor may be built in the near future. The Latina project being built by The Nuclear Power Group and Agip Nucleare is the only one in Italy at the moment.

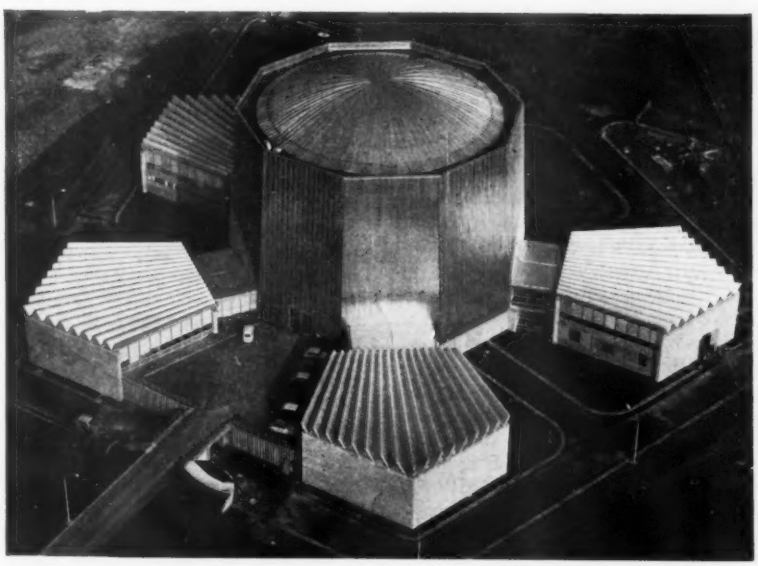
NETHERLANDS

A FEATURE of the 10 kWt Jason (Argonaut-type) reactor supplied to the Reactor Centrum Nederland by Hawker Siddeley, which went critical in October, is that the enriched uranium fuel was supplied by the USA—the first time US enriched uranium has been transferred to a foreign government to charge a reactor built in a third country.

Still under consideration is the 150 PNEM utility company's project in North Brabant province, a 10–30 MW homogeneous aqueous suspension reactor by SEP, a nine-utility cooperative, and a research reactor to be built at Wagenigen for agricultural research. A 250 kW quasi-homogeneous suspension reactor, SUSOP, is due to come into operation at the KEMA laboratory soon. The reported discovery of a large deposit of natural gas, said to be the size of the French Lacq field, may radically alter future nuclear plans.

NORWAY

THE Halden boiling heavy water reactor, which produced steam for the first time in October, tended to overshadow other developments. Nevertheless, important work has been carried out. A zero energy reactor, NORA, is being built at Kjeller and is expected to come into operation early in 1961. The IAEA has been invited to



ITALY The Sorin Nuclear Centre's RS-1 swimming pool reactor, the first privately owned applied research reactor in Europe

UNITED KINGDOM Construction of the 275 MW Berkeley nuclear power station, due to go critical in 1961, moves into the final stage

take part in a joint experimental programme with this heavy water moderated facility. In addition, the Institutt for Atomenergi is planning a new research and isotope producing reactor; construction is scheduled to start in Spring, 1961. A waste disposal plant, being built by Noratom A/S at Kjeller, will treat 25 tons of liquid and low activity waste daily.

On October 5 the power of the Halden reactor was increased to 2 MW. The maximum power at which the reactor will operate with the present fuel charge of natural uranium in aluminium cladding is 5 MW. The second charge, of 1·5% enriched uranium oxide in zircaloy, will be installed in 1961. With this charge, the maximum designed power level of 20 MW will be reached.

The 450 kW JEEP research reactor, also at Kjeller, was out of operation for six months in 1960 due to a leakage in the primary circuit. A new tank was installed and the reactor went into operation in October.

POLAND

PRESENT plans call for a second research reactor and a 200 MW station by 1965. Both will be graphite moderated and gas-cooled. Natural uranium is expected to be the fuel. The country's power programme specifies 800 MW by 1970 and 1800 MW by 1975. Future plans include a processing plant for handle ore from the main uranium and thorium deposits in the southwest; production of nuclear grade graphite and the building of a graphite fabrication plant. Marine propulsion is being studied at the Institute of Nuclear Research where work is being done on an OMR for a 24,000 shp merchant ship of 25,000 tons with a speed of 20 knots.

PORTUGAL

CONSTRUCTION of the 1 MWt pool type reactor built by AMF Atomics was to have been completed by the end of the year. Meanwhile, tentative plans have been made for acquiring an Argonaut-type research reactor. Other plans have not been finalized. These include the 100 MW power plant for 1965 completion which has been a Junta de Energia Nuclear project and the small reactor, also to be built by 1965, in which Companhia Portuguesa de Industrias Nucleares has expressed interest. Construction is proceeding on the pilot plant for producing uranium metal and future plans call for a 200 tons/year plant as well as a concentration plant near Guarda.

RUMANIA

STUDIES are in hand to build a uranium ore processing plant but little further news has been received of plans revealed at the 2nd Geneva Conference for 500 MW by 1975.

SPAIN

CREDIT terms will be a key factor in deciding the type of nuclear power station Spain will build under its programme for 1800 MW by 1975. This was the opinion of Sr J. MacVeigh, director of CENUSA (Centrales Nuclares SA), when he visited London during the year. However, a general 'wait and see' attitude exists in Spain and though three projects have been discussed, positive steps will not be taken until operating experience of various types of stations has been gained elsewhere.

The Junta de Energia Nuclear's (JEN) plans moved a step further forward when Atomics International submitted a design for a multipurpose 30 MW plant at JEN's request. This was for an OMR. Westinghouse and General Electric of the US have made similar design studies for JEN for a PWR and BWR respectively.

The uranium ore processing plant at Andujar near Seville was officially opened. It is near the mines at Santa Maria la Cabeza and Cardera and its capacity is about 200 tons a day.

SWEDEN

BIDS FOR a 50–60 MW BWR for 1965 operation are being considered by AB Atomkraftverk, an affiliate of the AKK Atomic Power Group. The station is to be situated on the Simpevaarp Peninsula, in southeastern Sweden. Two groups, with American associations, have submitted bids.

The 100 kWt critical assembly, R-2-0, and the 30 MWt materials testing reactor, R-2, came into operation during the year. Future plans include building a fast zero energy reactor, F-R-O, for operation by 1962 and probably instituting plutonium production at a small separation plant at Studsvik. Pemission has now been given for the building of the 100 MW Marviken station, 95 miles southwest of Stockholm, with the completion date set for 1967. Work is also being concentrated on the Agesta (R3/ADAM) station, due for 1962 completion.

SWITZERLAND

CONSOLIDATION of all industry and government activities into a federally supported project for the design and building of a heavy water moderated plant followed a re-examination of costs in the middle of the year. A major task for the Institute for Reactor Research at Wurenlingen will be to provide research and development support for this industry-government 30 MW natural uranium project.

UNITED KINGDOM

RE-THINKING resulted in the official building programme being reduced in June. The 1957 plan of 5000–6000 MW by 1966 was revised to a goal of 5000 MW by 1968. This was

an expected move and confirmed the actual rate of ordering of about one new civil station a year. The Government White Paper announcing this admitted that nuclear power could not compete with conventionally produced power for at least another ten years. It argued that atomic power, however, was of potential importance to the British economy and, as such, required continuous development—at the rate of 'roughly' one new station a year. No clear announcement was made for plans after 1968 though it was implied that the remaining 1000 MW might be installed by 1970. However, provided the impact on the consortia is not too severe, there are indications that the revised programme may be stretched out to 1970.

Research projects

This would be in line with the changed emphasis developing in AEA research which is now leaning towards slighly enriched systems. It would also reflect cost and building difficulties over the Advanced Gas-Cooled reactor and a swing towards developing systems giving low cost power instead of marginal advantages. Research is being focused on heavy water systems, fast and breeder reactors and the high temperature gas cooled system.

Close examination is being given to the steam generating heavy water concept and the AEA are continuing their studies before deciding whether or not to build a prototype. As part of a larger investigation into various concepts moderated by heavy water and cooled by either boiling light water or light steam, a short design survey of a 30 MW spray-cooled reactor has been completed. Work on these concepts is also being carried out in conjuction with Canada.

CZECHOSLOVAKIA A new view of the 2 MWt swimming pool research reactor which went critical in 1957 at the Institute of Nuclear Physics in Rez. Similar Soviet designed reactors are in East Germany, Poland, Hungary and Rumania

The development of the AGR posed some difficulties. In May, the AEA announced that an 80% proportion of beryllium canned elements was to be used for the first loading but in November said the proportion would be 20% beryllium and 80% stainless steel. The change was not officially thought of as a serious setback but to some observers, did seem to indicate that resolving the problems of the handling and the behaviour of beryllium was taking longer than expected.

At about the same time as the cuts in the nuclear programme were announced, discussions started between the CEGB and the consortia on the possibility of compensation for tenders. The amount was said to be £100,000 per tender. Various reasons have been put forward for these discussions with the two most often given being the cost of tendering and the need to develop the magnox stations to their economic limit. It has been estimated that about 30 unsuccessful tenders have been submitted to the CEGB, costing about £3 million. The talks seems to be a recognition of an existing state of affairs by the CEGB for the consortia will, in effect, include the cost of tendering in the price of future stations. A new note was introduced late in the year with the CEGB announcing that it was thinking of an 800 MW station for Wylfa Head, Wales. It is also believed the Board would favour a concrete pressure vessel for Oldbury.

The abandonment of the large thermonuclear experiment, ICSE (Intermediate Current Stability Experiment) was announced on scientific and financial grounds. The amount of scientific manpower it would take plus a doubling in the orginal estimate of cost had made this necessary. Research is to be directed toward the basic problem of achieving plasma stability. The announcement, Sir William Penny pointed out, did not mean that the AEA intended to give up its fusion research programme but that a variety of approaches were being planned.

Export prospects remained poor with only Latina and Tokai-Mura being built and a Brazilian and Indian station likely future prospects. Some indication of industry's dissatisfaction with the current state of affairs was given in their replies to a *Nuclear Power* survey. In brief, the replies suggested that further reactor types should be developed; there should be rethinking on small reactors; development should be speeded up on the HTGC and fast breeder and that a government export policy was needed.

NORWAY The 5 MW Halden Boiling Heavy Water Reactor which produced steam for the first time last year.

Despite some teething difficulties, notably over fuel element design, work on the Berkeley and Bradwell stations proceeded as expected. The CEGB programme made further progress when the 550 MW Dungeness station contract award went to the Nuclear Power Group and the 580 MW Sizewell station, the largest yet to be built, went to the English Electric Group. Hinkley Point and Trawsfynydd work went ahead steadily but further delays were announced with Hunterston whose completion date is now 1961–63.

A decision is expected soon on the reactor concept to be used for the 65,000 ton tanker for which design tenders were submitted in July. The evaluation report was to have been submitted to the Ministry of Transport in December and it is understood that two reactor concepts have been recommended.

USSR

WHEN THE Ministry of Power Station Construction outlined plans for the current seven year period early in the summer, there was no mention of nuclear power stations. Apparently there has been no change in policy since the 21st Party Congress agreed to extend the nuclear power programme to produce 2000-2500 MW by 1965.

According to the Ministry, annual power production will be raised to more than 500,000 million kWh under the Seven Year Plan. Soviet planners also expect that between 1965-70, new power plants producing 75,000 MW will be put into operation and by 1970, annual output will be 900,000 million kWh.

It thus appears that the basis of the nuclear power programme still remains an 'experimental construction programme intended to enable the selection of the best methods of developing atomic power in the future' (Kurchatov). A much greater reliance is being put on oil and natural gas, with the coal industry increasing its productivity. Under the present plan, natural gas supplies will be increased five-fold and oil supplies doubled.

The fast reactor team which visited Britain in January gave some information on its work. Dr Oleg Kazachkovski, Scientific Member of the Fast Neutron Reactor of the Institute of Physics, said there were plans for larger breeder reactors (than the BR-5 at Obninsk). Designs were in hand for a 50 MW (BN-50) which would be used to establish economic operating levels and for a 250 MW plant.

Indian visit

Other visits were made by Soviet teams during the year, notably to India, where an agreement for co-operation which would provide for the construction of a reactor was discussed. In April came an agreement with France on an exchange of visits and of information. During the year, two Soviet visits were also made to the USA; one dealt with high energy physics and the other with controlled thermonuclear research.

Work is progressing steadily on the Byeloyarsk station (now named the Kurchatov station). The first two reactors are under construction and are to be in operation in 1961–62. The other two 100 MW reactors for this projected 400 MW station will be built when sufficient experience has been gained with the first two to warrant construction. Each of the reactors will produce superheated steam from nuclear heat. A feature of the station is that the control panel will be 23 feet below ground level.

On other stations, the one at Voronezh on the Don River is progressing and the single 210-MW PWR under construction, using uranium oxide fuel elements clad in zirconium, is expected to be completed in 1961–62. A further reactor of the same capacity is to be built at the station later. Although the 2 MW mobile PWR at Obninsk was scheduled for 1959 completion, this has not been officially confirmed. Neither has there been any significant development reported about the Siberian dual-purpose, plutonium-optimized reactor station which is to have six 100 MW reactors —one is in operaton.

The 16,000 ton ice-breaker *Lenin* has been operated successfully in the Soviet Arctic and in view of the importance of such vessels in the North, construction of further such vessels may be expected. It is also reported that a nuclear propelled whaler is being developed.

Research and educational reactors are now installed in the Physics Institute of the Ukrainian Academy of Sciences in Kiev, the Georgian Academy of Sciences in Tbilisi and in the Uzbek Academy of Sciences. Construction work is well under way on reactors in Latvia, Byelorussia and Kazakhstan. In Sverdlovsk, the Urals, and in Tomsk, Siberia, polytechnical institutes will also have research reactors of their own. According to Professor Vassily Yemelyanov, head of the Central Atomic Energy Administration, special importance is attached to homogeneous reactors and the existing programme envisages such a reactor of 35 MWt.

YUGOSLAVIA

GRANTS were made by the US towards the cost of a 100 kWt Triga reactor at the Joseph Stefan Nuclear Institute and for a hot laboratory for the Boris Kidvic Institute. A request was also made to the IAEA for 6·5 tons of heavy water for the zero power reactor at Vinca. Production of radioisotopes was increased and will eventually meet all domestic requirements.

NORTH AND SOUTH AMERICA

CANADA

THERE are two nuclear power projects under construction in Canada. The first is the Nuclear Power Demonstration (NPD), a 20 MWe station, construction of which is well advanced at Rolphton, Ontario. Initial operation is scheduled in 1961. The second project is a full scale 200 MWe station, construction of which has begun at Douglas Point, Ontario, on the eastern shore of Lake Huron. The reactor for the station was named CANDU during the design phase but the project is now referred to as the Douglas Point Nuclear Power Station.

The layout of the Douglas Point station allows for the additon of a second 200 MWe unit but this has not yet been authorized. The addition of the second unit would reduce the net unit energy cost by 12–15%.

For power stations smaller than 200 MWe, a natural uranium fuelled, heavy water moderated reactor using an organic coolant appears promising. However, a number of technical problems require further detailed study. Design and associated development work is continuing on this type of system and a preliminary design is being prepared of a 40 MW thermal reactor called OCDRE which will be both an experimental reactor and a reactor experiment.

AECL has chosen a site for a new research and development centre in Manitoba to be known as the Whiteshell Nuclear Research Establishment. It is on the east side of the Winnipeg River, some 60 miles northeast of Winnipeg. Plans are being prepared for the new centre and for a new townsite nearby. It is likely that the first major facility there will be the organic cooled, deuterium moderated reactor experiment (OCDRE).

A new research reactor, ZED-2, to study fuel arrangements for power reactors has gone into operation at the main Canadian atomic energy laboratories at Chalk River. The four other Chalk River reactors (NRU, NRX, PTR and ZEEP) were fully used during the year. The seven loops in NRX and the two in NRU have also been fully employed to test fuel for nuclear power stations under conditions of high temperature and pressure and in the presence of radiation. These loops have been extensively used by the USAEC and by the UKAEA.

The Canada-India reactor (an improved version of the Chalk River NRX) came into operation near Bombay in July 1960. CIR was built under the Colombo Plan and in this project, Canada has made the world's largest single contribution in international assistance in the atomic energy field.

In mid-1960, AECL shipped its millionth curie of radioisotopes. More than half of this reactivity has been in the form of high specific activity cobalt-60, largely in beam therapy machines for the treatment of cancer. It is estimated that Canadian-made machines in 30 different countries are now providing 100,000 cancer treatments each month.

SOUTH AMERICA

MAIN developments have centred on **Brazil** where tenders are to be invited for a 150–200 MW reactor to be built by the Mambucaba River. The construction contract will probably be

signed in January 1962, Sr Octavio Dias Carneiro of the Brazilian AEC told the 3rd Inter-American Symposium on the Peaceful Applications of Nuclear Energy. Commissioning is set for 1966. Future plans include intensive exploration for uranium ore; increased ore processing facilities and use of the Sao Paulo 5 MW swimming pool reactor to supply most of the country's isotope needs.

In **Argentina,** chief emphasis has been on raw materials with some 25% of the Commission's budget being spent on exploration, mining and processing. An ore processing plant is to be built at Malargue and uranium exports are likely to be increased.

In **Bolivia** and **Chile,** progress has been slow and steady. Generally, plans have concentrated on the use of isotopes. **Colombia** intends to acquire a research reactor and build a nuclear physics and an isotope laboratory.

Cuban developments have been coloured by political events but unconfirmed reports say a Russian 20 MW reactor is to be built near Havana.

Of the other South American countries, **Venezuela** takes pride of place as her first research reactor, IVIC, went critical during the year. This is expected to lead to intensified research and increased use of radioisotopes. In **Mexico** and **Peru,** plans exist for setting up a subcritical assembly and in the former country, work went ahead on developing the uranium industry and on designing a ten-ton daily ore processing plant. **Ecuador** is also interested in small reactors for areas not having hydroelectric power and also in a research reactor; in **Uruguay,** a basic atomic energy law needs to be passed before plans for a research and training reactor can go forward.

UNITED STATES

TWO EVENTS stood out during the year — the ten-year programme outlined by the AEC and the McKinney report on US international policies and programmes. The latter to some extent revised the near-term outlook of the AEC programme.

The AEC programme aims at making power from large nuclear plants economically competitive with that from conventional plants in high fuel cost areas. It called for the expenditure between 1961–60 of an average of $M200 a year; contemplated the allocation of $M700 for research and development of specific projects; spending $M365 for at least 14 prototype power reactor plants and $M645 for general engineering and design work in support of the civilian power reactor programme. The primary emphasis was on 300 MW plants because it was felt that these large sizes would more easily and quickly prove to be economic.

USA Over 50% completed, the sodium cooled, graphite moderated 75 MW Hallam Nuclear Power Facility in Nebraska is due to go critical in 1962

The AEC estimates that light water and organic reactors can be built by 1970 at capital costs per installed kilowatt of between $180 and $230 and operating costs respectively of 2·9 to 2·5 mills/kW. Soon after the AEC presented its programme, a move towards the short-term goal took place. Southern California Edison Co. announced its intention to start building a 360 MW PWR in 1961. This will take four years to complete and is expected to produce energy at 7·3 mills per kilowatt hour.

In an October report, 'The Future Role of the Atomic Energy Commission Laboratories', the short-time aim was again restated and the long-term goal given as eventual achievement of low cost atomic power with maximum fuel burn-up.

Despite the controversy which gathered around the compilation of the McKinney report, it turned out to be a sober appraisal of US and European views on nuclear power. The review embraced 'US relationships with industrialized and less developed countries with allied countries and with Communist-dominated countries'.

One of the conclusions of the report changed the emphasis of the AEC's short-term aim of competitive nuclear power in high cost areas. This was now of diminishing validity, the report said, because of the disappearance of high cost energy areas. Future US planning should focus on making atomic power offer appreciable rather than marginal cost advantages. The US should make the achievement of low cost power a primary objective and the broader benefits of atomic research a collateral objective.

Looking ahead

Future trends can be summarized as follows:

PWR: Concentration on solving the problems of nuclear superheat; cutting fuel costs; extending fuel life and lowering construction costs. Advanced PWR types may be built in 1961–62 to take in experience from Shippingport, Yankee and Indian Point.

BWR: Main concentration is on superheat fuel elements. A 100 MW superheat prototype is being considered but larger types may not be built until experience has been gained with such plants as the 16 MW Elk River and the 50–75 MW Consumers Power project.

OMR: Research is proceeding but a large plant is unlikely before 1965 despite the attraction of low capital costs.

SODIUM GRAPHITE: Until the 75 MW Hallam project is operating, it is unlikely that work will go beyond research on fuel element problems.

FAST BREEDERS: This is a long-range project but immediate plans have been delayed with legal difficulties over the 100 MW Enrico Fermi project.

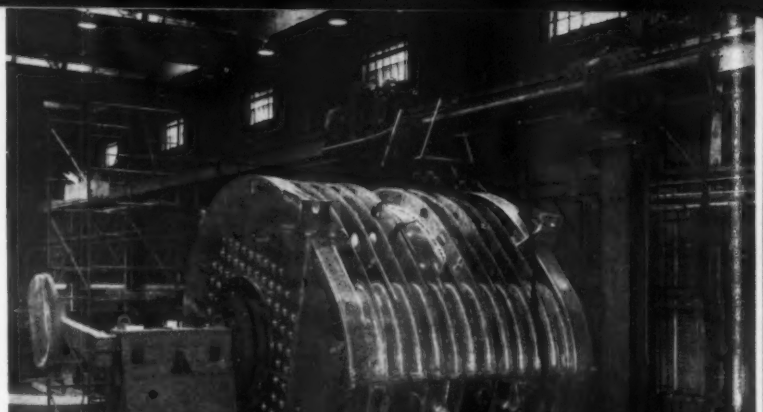
GAS-COOLED: More emphasis is being placed on this type and a vigorous programme is being developed. General Dynamics has a development

programme underway for a 300–500 MW HTGR to be placed in operation in New York State.

HEAVY WATER: There is closer co-operation with Canada through the signing of an agreement in the autumn and, as with the gas-cooled, more emphasis is being placed on the programme. The Carolinas-Virginias 17 MW project is scheduled for 1962 criticality.

AQUEOUS HOMOGENEOUS: Research and development is continuing on a long-term basis and a 50 MW prototype may be built.

GENERAL: By the end of the year, US utilities had 17 power projects planned or building which should provide some 1800 MW when completed and involve an expenditure of about $M650. Some 460 MW was scheduled to be in operation by the end of 1960.



CANADA The NPD reactor under construction at the Canadian General Electric Co. Ltd at Peterborough. This 20 MW heavy water moderated reactor is well on its way to completion

ASIA AND AUSTRALIA

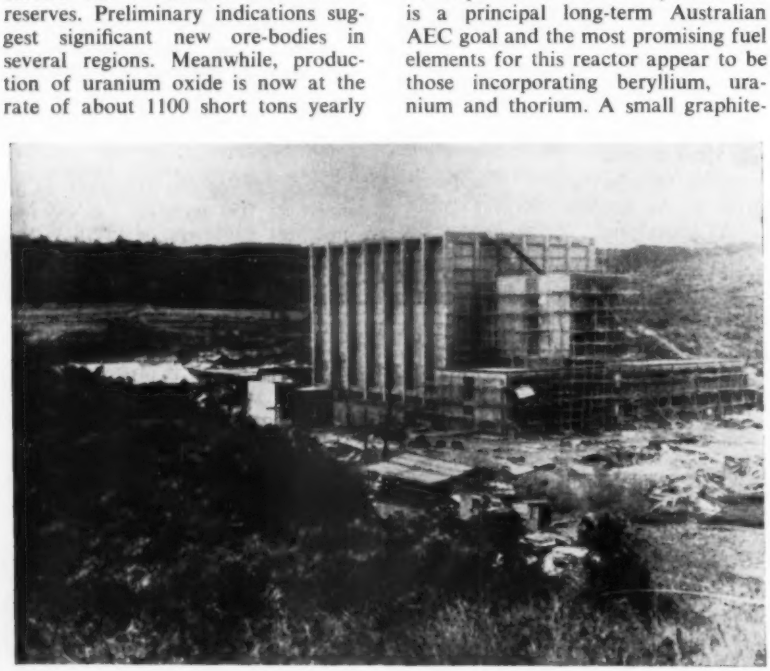
AUSTRALIA

PRODUCTION of raw materials, research into the high temperature gas cooled reactor system and the production and use of radioisotopes, were the main features of development in Australia during the year.

A regular programme of aerial and ground surveys and exporation was carried out to extend uranium ore reserves. Preliminary indications suggest significant new ore-bodies in several regions. Meanwhile, production of uranium oxide is now at the rate of about 1100 short tons yearly from five enterprises—two governmental and three private companies.

The testing reactor HIFAR was brought up to its full power of 10 MWt at the beginning of 1960 and has been operating smoothly since. It is being used to produce isotopes and for intensive research into nuclear materials which are being considered in the development of the HTGC system. This is a principal long-term Australian AEC goal and the most promising fuel elements for this reactor appear to be those incorporating beryllium, uranium and thorium. A small graphite-moderated reactor is also being installed at the Commission's research establishment for physics studies of reactor materials and sample cores.

Generally, nuclear power is considered only likely to be economic for installation first in South Australia and Northern Queensland, the first units being commissioned about 1970. Between 1970 and 1980, nuclear power should also become economic in Southern Queensland, Tasmania and the Northern Territory, a total of about 1000 MW of plant being installed during this decade.



FORMOSA Construction of this country's first nuclear research centre was due to be completed at the end of December 1960. The centre (above) will have a 1 MW pool type reactor

CHINA

LITTLE positive information came from official sources during the year though progress continued steadily. A heavy water research reactor with a capacity of between 7000 and 10,000 kW is in operation. In addition, a 25 MeV spiral cyclotron together with a domestically designed 2·5 MeV proton electrostatic accelerator are in use.

During the year training at the Dubna research institute was provided for Chinese technicians. Home training and research work was undertaken at Peking and at the Urumchi research institute headed by Professor Chien Hsueh Shen.

No confirmation was received of reports of a reactor operating in Sinkiang province and future plans are not known though by the end of the present Five Year Plan (1962), it is hoped to have a power production of 40,000 million kilowatt hours a year.

INDIA

LATE in the year, international tenders were invited for a 300 MW station consisting of two 150 MW units and fuelled by natural uranium. The £38 million project will be located at Tarapur in the Bombay-Ahmedabad region and is scheduled for completion in 1965. Bids are to be submitted by May 31, 1961. An interesting sidelight is that Fuji Electric Company say they have been invited to submit a tender; should they do so, it will be the first time a Japanese company has submitted a tender for an overseas nuclear power station.

Another highlight was the coming into operation of the Canada-India (CIR) 40 MW research and engineering reactor. Another research reactor, a zero energy facility, also came into operation at Trombay.

The Indian AEC expects to have an additional 300 MW (natural uranium fuelled) station installed during the Third Five Year Plan. One 150 MW unit is to be in operation by March 1966 and will be linked to the Delhi-Punjab grid. The location of the other 150 MW unit has not been finally settled. It is also proposed that 100 MW be installed in stations using enriched uranium. One station, of 75 MW, probably a PWR, is to be located in the Delhi-Punjab area and is to be commissioned by mid-1964. This other will probably be a 25 MW OMR, situated in the Rajasthan area. Talks with France, the UK, USSR and the US on assistance for this programme were held during the year.

Should present cost figures regarding building prove to be too optimistic, the first stage programme, of natural uranium reactors producing plutonium for subsequent stages, will be stepped up. Difficulty over the plutonium and the safeguards question may arise as Dr H. Bhabha came out against the safeguards system at the IAEA Conference.

INDONESIA

BILATERAL agreements were signed with the US and the USSR. A Triga training and research reactor, to be supplied under the US bilateral, is scheduled to go critical by the end of 1961. A Russian sub-critical assembly was due to go critical at the end of 1960. In addition, a Soviet research reactor, plus financial assistance, may be supplied during the coming year.

JAPAN

IN THE first quarter of the year, there was a downward revision of the nuclear programme. This brought the 1965 target to 300 MW from 600 MW and the 1970 target to 2000 MW against 7000 MW originally projected in 1957. A further report by the Ministry of International Trade and Industry in July said it would be necessary to construct 1000 MW by 1970. This would be in the 'preparatory stage'—before nuclear power became competitive with conventional power costs in Japan. In the decade 1970–80, nuclear capacity needed would be 6000–7000 MW or about 30% of generating capacity. The report added that it was necessary to encourage home production of reactors and nuclear fuels.

The Japanese AEC also set 1970 as the target date for a 'demonstration nuclear ship'. To achieve this, it included in the government budget for the 1961 fiscal year, funds for a pool type research reactor at the Japan Atomic Energy Research Institute. It would be primarily for carrying out maritime reactor shielding studies.

There was difficulty over nuclear liability legislation as the Diet was dissolved following internal disturbances during the year. The bill, which was introduced in the Diet in May, is not expected to be discussed until late in January 1961. Among the proposed provisions is one which assigns 'absolute liability' to the owner-operator of a reactor for damage caused as a result of the operation of the reactor or as a result of the transportation of nuclear fuel.

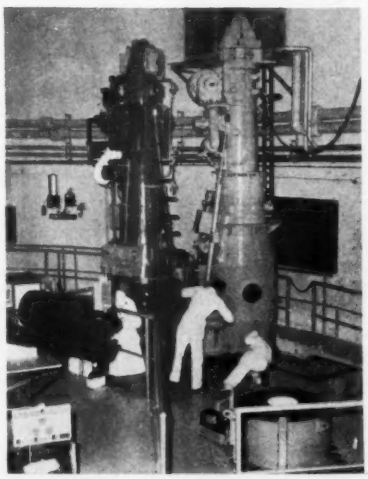
After lengthy negotiations, GE Japan Ltd signed a contract with the Japan Atomic Energy Research Institute to build a 12·5 MW BWR at Tokai Mura. Completion is scheduled for March 1, 1963. The original letter of intent was issued to GE in 1959 and was delayed because of the absence of Japanese nuclear legislation. However, the JAERI now waives all rights of recourse against GE except where nuclear damage is proved to have been caused by intentional official acts of GE's corporate officers or directors.

Approval was given for two 100 kW pool type research reactors to be built at Kawasaki City. One is to be constructed by Hitachi Ltd and the other by Toshiba in co-operation with the Mitsui combine. This latter reactor will be for the Musashi Technological University. Both reactors will be subsidized in part by the government and were to be completed by the end of 1960. The country now has nine research reactors built or building in addition to the 12·5 MW BWR and the 150 MW Tokai-Mura Calder type reactor being built.

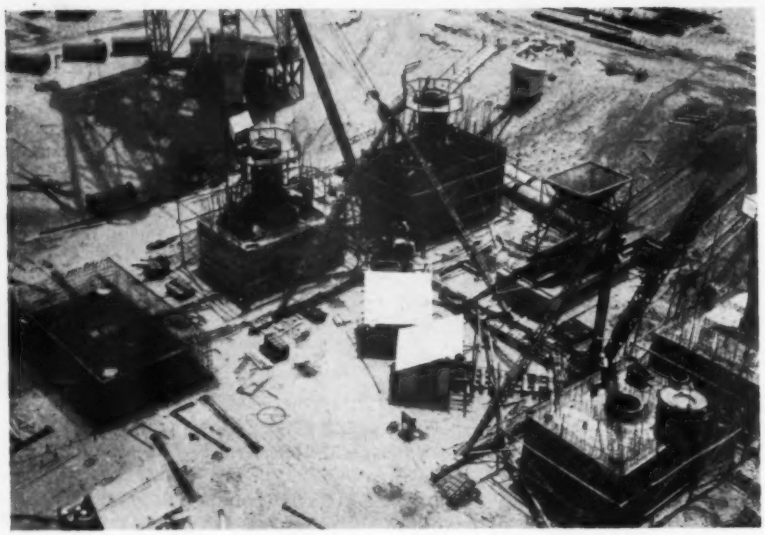
ISRAEL Situated on sand dunes near Rishon le Zion, this 1 MW AMF reactor started operations in the summer

REPUBLIC OF KOREA

THE director of physics research at the Armour Research Foundation, Dr Leonard Reiffel, spent three weeks in Seoul helping the Government set up a more comprehensive nuclear research programme in the next five years. The Atomic Energy Research



AUSTRALIA Research workers handling flasks on top of the 10 MW research reactor, HIFAR, at Lucas Heights, NSW



JAPAN Caissons at various stages of sinking at the site of the 150 MW Tokai-Mura station being built for the Japan Atomic Power Company

Institute expects to start building a power plant within five years time. Meanwhile, a Triga Mark II, supplied by General Atomics, was due for completion in 1960.

PAKISTAN

FIRST steps towards establishing an institute of nuclear sciences and technology at the new capital, Islamabad, were taken during the year. The US also undertook to provide money towards the construction of a 5 MWe pool type reactor supplied by American Machine & Foundry Co. This is scheduled for operation in the spring of 1963 with the total cost estimated at $3·5 million. No serious plans for a power programme have yet been developed.

OTHER FAR EAST COUNTRIES

Taiwan Studies are being undertaken by the Taiwan Power Company to decide whether it would be economic to build a power plant by about 1968. A swimming pool 1 MW research reactor at the Hsinchu Nuclear Research Institute is due to start up soon.

Burma A radioisotope laboratory for training and research is under construction.

New Zealand Hopes of finding significant uranium deposits were dashed after a AEA geologist's negative report. Work continued on an Institute of Nuclear Science and plans are being made for a research reactor in 1962–63.

Philippines An IAEA study took place during the year on power prospects. Plans are being made to extend the use of radioisotopes and construction is to start in 1961 on a 1 MW pool type research reactor.

Thailand A small 10 MW nuclear power plant is being studied by the Thais and the IAEA. The high cost of power in the country makes nuclear power possible in the near future.

Republic of Vietnam The Institute of Nuclear Research is preparing a research programme for the country's Triga Mark II reactor.

MIDDLE EAST AND AFRICA

ISRAEL

DURING the year, the Israel AEC established a new site at Nahal Sorek to house the 1 MW AMF swimming pool research reactor, the Radioisotope Training Centre, the Physics and Chemistry Research Departments and smaller units working on problems in biology and metallurgy. The transfer began with the putting into operation of the reactor which went critical in June. New buildings for hot laboratories, service departments, etc. are planned and are expected to be built in 1961.

TURKEY

THE 1 MW swimming pool reactor being built by AMF Atomics is due for completion in 1961 and a centre, to include a materials testing reactor and a power reactor, is planned once this research reactor is complete. How the changed political situation will affect this and draft plans for a civil power reactor to be built in 1970 is not yet known.

UAR

THE radioisotope laboratory being built for the Egyptian Atomic Energy Commission is expected to be ready in the autumn of 1961. Equipment and training advisers are being supplied by Noratom of Norway and ten Egyptian scientists are gaining experience at the Kjeller isotope laboratory. The 2 MW Soviet tank type reactor, obtained under the 1956 agreement, is due to operate in 1961. Newspaper reports say a uranium extraction plant and a heavy water facility will be built.

OTHER MIDDLE EAST COUNTRIES

Iran Plans exist for installing a 5 MW pool type research reactor at the University of Teheran.

Iraq An agreement for technical assistance has been signed with the USSR and contracts have been completed for building a 2 MW research reactor and an isotope production facility.

Lebanon Work on radioisotope techniques is to be extended.

SOUTH AFRICA

RESEARCH and development is still at a comparatively early stage but three major events were announced by the Atomic Energy Board. These were: the construction of a pilot plant for producing nuclear grade uranium metal and compounds from uranium concentrates; the purchase of land for the site of a national nuclear research centre and finally, the signing of a letter in intent to purchase a 20 MW ORR-type reactor from Allis-Chalmers Manufacturing Company.

Construction of the pilot plant is nearly completed and it will be capable of producing about 100 tons of metal annually. The future research centre at Pelindaba, 18 miles due west of Pretoria, covers a total area of about 2900 acres. It is expected that initial development work will start in earnest early in 1961.

The ORR-type reactor will initially be operated at 6½ MW but thereafter the power will be progressively increased until it ultimately reaches the maximum design rating of 20 MW. The nucleus of the Board's Reactor Operations Group has been attached to the manufacturers to assess the design work and to introduce modifications required for South African purposes.

The heads of the International Atomic Energy Agency, Euratom and the European Nuclear Energy Agency report on progress in 1960

The IAEA gathers momentum

by STERLING COLE,
Director General

IF I WERE to try summing up in a few words my impressions after our annual stocktaking, which the General Conference session in September–October represents, I would point to three things in particular. Firstly, the debates were of a more scientific and technical character than usual, in spite of the dramatic political discussions which were going on at the same time in the General Assembly. Secondly, many more practical proposals and suggestions were made by delegates this time than at earlier sessions. Thirdly, principles and procedures for the application of Agency safeguards were discussed at length and our governing Board given authority to go ahead. Even more important, perhaps, several countries indicated their willingness to place safeguards clauses in their bilateral agreements under the Agency's administration and the United States offered to place four reactor plants under our safeguards and inspection system.

Safeguards

The safeguards question was perhaps the most serious and difficult one with which we had to deal last year. The Agency's Board of Governors and Secretariat have been occupied with this problem from the outset of their existence. As a result of this prolonged consideration, but not without sharply dissenting views, the Board was able to propose a set of principles and procedures to last September's General Conference. The proposal involved an accounting system for keeping track of the use of nuclear materials and Agency inspectors who would have access, as needed, to the nuclear facilities of Member States.

The debate on safeguards in the General Conference mirrored to a large extent views previously expressed in the Board. There are sincere differences of opinion on this subject which, as the Board's Annual Report states, involves 'questions of an administrative character which are as novel as nuclear technology itself and involve long-standing concepts of international relations and sovereignty'. A majority vote of the Conference gave the Board a cautious go-ahead; it approved a resolution which took note

Sterling Cole
A break-through

of the principles and procedures provisionally approved by the Board and which invited the Board, before giving effect to them, to take appropriate account of the views expressed in the Conference. The ready acceptance by many countries of the proposed safeguards system represents, in my opinion, a break-through, a pioneering act of great potential importance.

There has also been considerable progress in the last year on atomic safety and in this field I expect our coming year to be particularly fruitful. The General Conference approved Agency-drafted regulations for the safe transport of radioactive materials. The Agency is also giving attention to safety questions affecting various other fields. In some cases we are trying to achieve an international convention; in others we expect that our recommendations will be put into effect through the individual actions of Member States; in still other cases, where the drafting of regulations might have a hampering rather than a stimulating effect, we are content with organizing scientific meetings and discussions. The Agency is also in a position to assist Member States with certain aspects of individual nuclear power projects. Of course, a most important means by which the Agency can assist individual projects of its Members is by facilitating the supply of needed materials and equipment.

Apart from these activities of direct benefit to individual Member States, the Agency has undertaken a continuing programme in which it makes general technical and economic studies and collects and distributes information on nuclear power.

The largest scientific meeting which the Agency has yet sponsored in the nuclear power field was the Conference on Small and Medium Power Reactors held in Vienna last September. This was the first large-scale conference dealing with this subject matter since the second (1958) Geneva Conference on the Peaceful Uses of Atomic Energy. At our conference it seemed clear that the emotional swing was cautiously, but nonetheless confidently, to the optimistic side again. Although it was emphasized that the period of proof for nuclear power lay just ahead, when a number of large plants would be operating, there was already much solid experience with small plants, considerable encouraging research and experimental work and a fair degree of consensus in carefully considered economic studies. These gave a nuclear power cost picture considerably brighter than the one last presented at Geneva.

Some misgivings

In this review I have expressed considerable satisfaction over the progress the Agency has made during the last year. There is ample basis for this feeling. Coupled with it, however, is a certain amount of anxiety and misgivings, as I stated in my address to the General Conference two months ago. As I said then, we have made a satisfactory start, but a start only, and the lack of wholehearted financial support, a tendency of weakening the effort through a proliferation of approaches, and the failure of governments to take greater advantage of the machinery and facilities available through IAEA, are all discouraging signs. The coming year must see a decisive effort by governments to support and use the International Atomic Energy Agency and to expand and strengthen its activities.

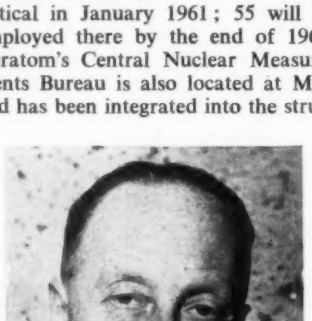
Euratom's year of expansion

by ETIENNE HIRSCH
President

'A YEAR OF expansion' — this is probably as good a way as any of summing up Euratom's activities in 1960, the third year of its existence. Certainly the urgent need for electricity has receded in Europe as in most other parts of the world and there is no immediate need for a large-scale nuclear power programme. On the other hand, 1960 has seen a great deal of spadework on the construction of a European nuclear industry: for instance, the opening of Community research centres, the establishment of the Security Control inspection team, the entry into force of German legislation incorporating Euratom's Basic Health Standards, and the Council of Ministers' decision to build a power plant as a Euratom 'joint enterprise'.

For the time being, the primary task of Euratom research is to develop reactors which will enable nuclear electricity to compete with imported oil and other fuel towards the end of the decade. Euratom is going about this in three ways: by acting to prevent overlapping between national research reactor projects, by setting up its own research centres and by joining in bilateral or international research projects. For 1961 a research budget of $M75 has been approved by the Ministers, half as much again as in 1960. The outstanding event in 1960 has been the ratification in July by the Italian Parliament of the agreement which puts the Ispra research centre at Euratom's disposal. Euratom is taking over this centre in stages, but it has already become Euratom's research headquarters and about 300 Euratom scientists and technicians should be at work there by the turn of the year.

Other Euratom research centres are being set up alongside national establishments in other member countries. Euratom has concluded an agreement with the Belgian Government under which the BR2 50 MW high-flux materials testing reactor at Mol will be operated jointly by the Belgian Centre d'Etudes de l'Energie Nucléaire and Euratom, and 20 Euratom technicians are taking part in the final operations on the reactor which is due to go critical in January 1961; 55 will be employed there by the end of 1961. Euratom's Central Nuclear Measurements Bureau is also located at Mol, and has been integrated into the structure of this second Euratom research centre. Other agreements are impending with Holland and the Federal Republic of Germany. The first, the finalization of which is imminent, follows a Dutch proposal to transform its Petten centre into a research centre for the Community, and under it Euratom will initially be involved in the operation of a materials testing reactor there. Under the second agreement, Euratom will be establishing a Joint Centre alongside the German Karlsruhe centre which will specialize in studying the potentialities of plutonium for power reactors. Apart from Euratom's own research programme, many research contracts—47 by the beginning of November—are being farmed to firms and national research centres in the Community.



Etienne Hirsch
Spadework

'Dragon' is undoubtedly the most important reactor research project with countries outside the Community. What is being done at Winfrith Heath needs no describing here.

The harnessing of nuclear energy for power production may only be going ahead slowly. Nevertheless two projects within the scope of the US-Euratom Agreement are under way. One is the Italian SENN plant powered by a 150 MW boiling water reactor, which should go critical in 1963. The second is the SENA project for a 240 MW PWR power station to be built for the Société Nucléaire Franco-Belge des Ardennes, an association of French and Belgian Companies. It has been decided that the importance of the SENA project justifies the status of 'Joint Enterprise'.

Euratom is also becoming increasingly concerned with other sectors of the power field. One is marine propulsion. Euratom has agreed in principle to participate in a German project to study an OMR-type marine reactor, and the Community has been asked to join in research and development work on a PWR-type marine reactor for an Italian grouping. Research into the use of thermonuclear power for electricity production is still in its infancy. So far, 30 Euratom scientists are working in the 70-strong joint CEA-Euratom team at the French Fontenay-aux-Roses centre, while a research contract in the field of plasma is to be given to the Max-Planck-Institute at Munich.

New ground

New ground has been broken in other directions. The Supply Agency, a special department of the Commission, with its own legal personality and financial autonomy, was set up on June 1. While the glut in the supply of uranium and other raw materials lasts, the Agency will give automatic approval to private contracts and will waive its right of option on them, a power which may one day be needed in order to ensure that all consumers have equal access to supplies.

Euratom's Security Control system is now in operation. This is, in fact, the first international security control system to have legal force over a group of nations.

Last, but certainly not least, health protection. Early in 1959, the Euratom 'Basic Health Norms' were approved and these again are the first obligations of their kind to be binding on governments. In September 1960, the German radiation protection legislation based on the Health Norms, came into force; and they are being incorporated into the legislation of the other member countries.

All in all, 1960 has been a year in which Euratom has got to grips with a number of often tiresome and tedious problems which must be solved before a single Community industry becomes a reality. Above all, Euratom has embarked on the search for cheap nuclear power production.

The work of the ENEA

by PIERRE HUET
Director

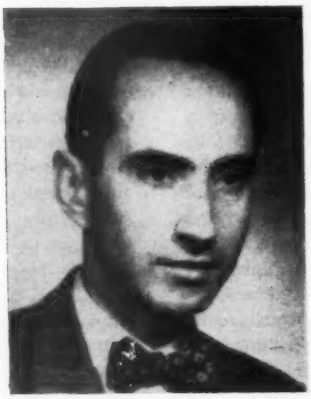
NUCLEAR ENERGY in Europe is at present going through a phase of reappraisal. The need to produce nuclear power quickly and virtually regardless of cost, already fading during recent years, has now disappeared and been replaced by the need to make it competitive before it will sell. This has been reflected by a slowing down of national power programmes, a greater concentration of effort on research and development directed towards reducing costs, and a general tendency to pause.

These changed circumstances offer some very real advantages. Additional time to explore alternative possibilities more thoroughly is the only way to determine, rather than conjecture, the advantages of various types of reactor, different methods of utilization and operation, and different fuel arrangements and fuel cycles. This is why ENEA, which has always devoted a great deal of attention to research and experiment designed to explore and assess the values of different systems, sees in Europe's improved energy situation, a useful opportunity to consolidate past advances and lay a sound foundation for the future.

International joint undertakings are especially valuable for this purpose. In addition, it seems desirable at the present time to seek a greater co-ordination of *national* research and development schemes, designed to avoid duplication and to ensure full interchange of knowledge and experimental results. A way of achieving this is through international committees of experts in various specialized fields, meeting to discuss programmes and to agree on the best use of all available facilities in the common interest. The European-American Nuclear Data Committee, set up by ENEA in 1959, is an example of this.

Finally, the development of nuclear energy has posed a number of economic, social and legal problems, many of which demand a uniform solution for countries in close geographical association. Here ENEA provides a sufficiently broad framework for achieving agreement among all European countries.

The European Company for the Chemical Processing of Irradiated Fuels (Eurochemic), the first ENEA joint undertaking to be planned, came into being on July 27, 1959. Since then a 'cold' testing station for carrying out full-scale trials with experimental processing units has been commissioned and here, as well as in laboratories made available to the Company by the Belgian Centre d'Etude Nucléaire, research is proceeding on various problems.



Pierre Huet
Reappraisal

Last June, a contract was concluded with the French company Saint-Gobain for the preparation of a detailed plan for the plant proper, and construction work on the site was inaugurated on July 7 by HRH Prince Albert of Liège.

To provide opportunity for industry in all the participant countries in Eurochemic to gain experience from the project, contracts are being placed with a group of seven architect-engineers for building the plant and ancillary installations.

The boiling heavy water reactor of the Halden Project in Norway, which first went critical in June 1959, achieved boiling on October 5, 1960. This was the first time that steam had been generated in a reactor of this type, and marked the beginning of the Project's experimental power programme. The main objectives of this programme are to investigate in detail the potentialities of a boiling heavy water reactor.

On April 27, 1960, at the UK Atomic Energy Establishment, Winfrith, a ceremony was held to mark the start of construction work on the Dragon Project's experimental high-temperature gas-cooled reactor.

It is clear that if maximum benefit is to be derived from the international character of the Project, the fullest possible participation by European industrial firms is necessary. To achieve this, a system of international competitive tendering for the supply of the various elements required (including in some cases the design of plant and equipment) has been instituted. A number of important contracts have been placed and the total value of those concluded to date exceeds £1,500,000.

Co-operation in research

The three joint undertakings must be regarded as complementary to research and development on a national basis. Such national effort must continue to play by far the greater part in each country's nuclear programme, and it is therefore one of ENEA's fundamental tasks to help ensure the best possible use of resources by co-ordinating work wherever possible.

International co-operation is valuable for the measurement and evaluation, on a uniform and comparable basis, of environmental radioactivity in different countries. Here ENEA has carried out a survey of Europe's monitoring systems and equipment, and is acting as a European clearing house for measurements made by these.

Much interest has lately been shown in the preservation of food by nuclear irradiation, and ENEA has set up a Study Group to review the work of Member countries and to examine what practical action might be taken to stimulate further development.

Another ENEA Study Group is to examine the work of different European countries on nuclear ship propulsion, and to investigate the possibility of closer international collaboration.

The Agency has already established, in collaboration with Euratom, uniform European health and safety standards, and ENEA's international Convention on nuclear third party liability has now been signed by 16 countries. Problems concerning the safe transport of highly radioactive materials and the safe disposal of radioactive waste are at present under study; in this work there is close collaboration with the International Atomic Energy Agency, and a recently concluded agreement puts on an official basis, the considerable informal co-operation already existing.

These four articles review developments during the past year in reactor engineering, nucleonic instrumentation, process chemistry and applied irradiation

PROGRESS IN TECHNOLOGY

1 Reactor engineering

by R. F. W. GUARD, B.Sc.(Eng.), A.M.I.E.E., Chief Engineer, Nuclear Dept., Kennedy & Donkin

WHEN CONSTRUCTION starts on Candu, the 200 MWe Canadian station, it will be the first time in three years that work has begun on a full scale prototype of a basically new reactor system. The three large American stations are almost complete and all new reactors in the USA are being built in smaller sizes. The Russian civil nuclear power plan has been heavily cut and has faded into obscurity. Sweden still goes it alone in spite of her small resources. The French programme makes slow progress, but ambitious technical steps are being taken between successive reactors and the CEA are now seriously considering abandoning graphite for heavy water. Britain alone presses doggedly on with a string of giant stations, each one differing only marginally from the last.

Gas cooled reactors

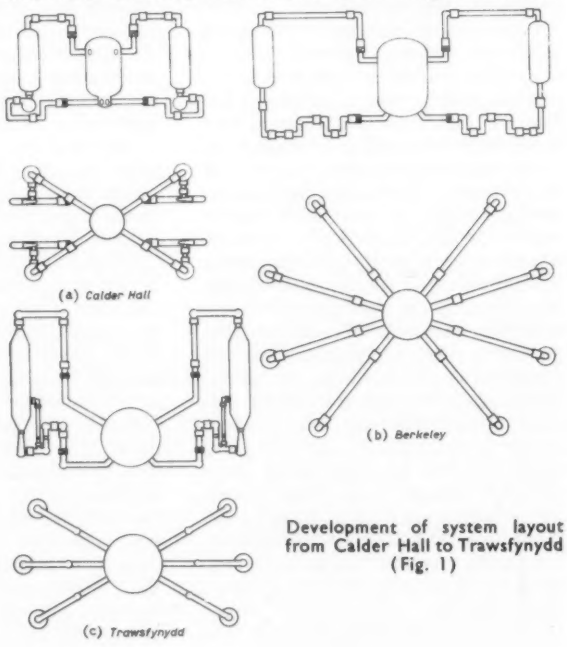
Amid growing criticism the Central Electricity Generating Board have placed another two orders during the year for new stations to be built at Dungeness and Sizewell. Published design data is meagre, but few really new design features appear to have been incorporated.

The close collaboration between designers and the purchaser in the pre-tender stage means that the final proposal, if not actually dictated by the CEGB, then at least has their *prima facie* approval. With fourteen industrial reactors now contracted for in Britain, it is very disappointing that the last should so closely resemble the first in its basic lay-out. It would be interesting to know whether this is due to deliberate CEGB policy or whether designers simply fear that their proposals stand less chance of acceptance if they are unconventional.

Figure 1 shows the development of system layout from Calder to Trawsfynydd. The first step was to construct the ducting and boilers in one plane; subsequent designs have reduced the number of gas circuits from 6/8 to 4 in spite of considerably increased power. Advanced layouts which have been suggested are shown in Fig. 2.

Pressure vessels Gas pressures in the latest British designs still do not approach the EDF-2 figure of 355 lb/in²a (*1*). Plates for the Sizewell vessel will be over 4 in thick and must be close to the economic limit for carbon steel. There are many suggestions for methods of increasing pressure. Alloy steels are being closely examined but these are not being produced yet in sufficiently large billets, and the steelmakers will not develop them until the demand is guaranteed. The AEI/JT pre-merger idea of a reinforced cylindrical vessel was not adopted for Dungeness but remains as a possibility. A much more probable candidate is the pre-stressed concrete 'caisson' or combined pressure vessel and biological shield, which has been used successfully in France for the production reactors and which is to be adopted for EDF-3. Two excellent papers (*2*), (*3*) recently read in London explain the idea but Davidson's admission that his paper was 18 months old shows that no crash-development programme has been initiated in Britain. The idea of the most highly stressed components (the tension cables) being away from the neutron flux and high temperature gas is immensely attractive. There are signs that this system is being closely studied for Oldbury.

A paper from Lloyds Register (*4*) discussed vessel inspection and raised the question of hydraulic pressure testing. Hot water must be used to avoid the danger of brittle



Development of system layout from Calder Hall to Trawsfynydd (Fig. 1)

fracture. This method is to be used at Latina and for the EDF reactors, but with vessels now satisfactorily tested pneumatically in the UK the question still remains open. Hydraulic testing would be essential for concrete vessels.

Thermal cycle A notable increase in thermal efficiency is claimed for Dungeness using the steam-driven gas-circulator cycle with re-heat (*5*). The principle is not new, having been used at Tokai-Mura where the higher C.W. temperature did not allow such impressive efficiencies. However, it would be a mistake to assume that the steam driven circulator is now supreme, as Sizewell will use electric motors, driving vertical axial circulators with inlet vane control and by-pass ducting ingeniously located within the main boilers. Efficiency may be lower but a squirrel cage motor takes a lot of beating for simplicity and reliability.

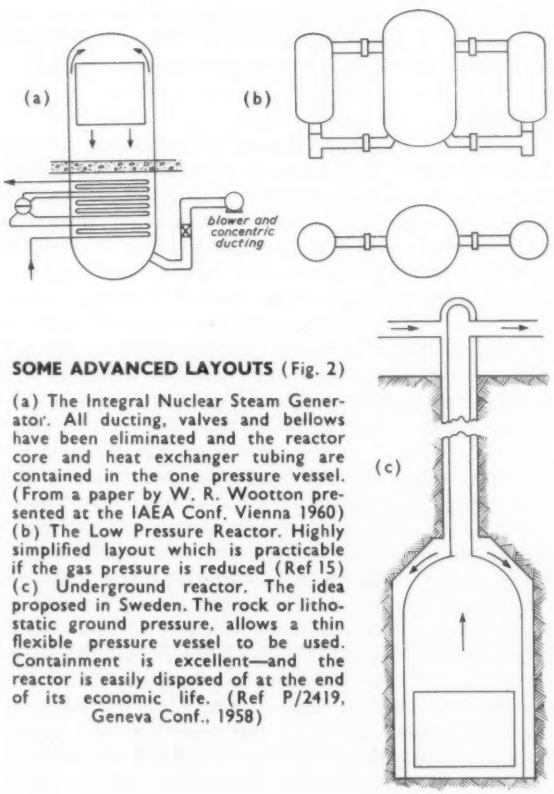
Dungeness uses higher steam pressure than ever before with, of course, no important increase in temperature; hence the turbine exhaust wetness of 14·3% is a little on the high side by normal standards. That turbine designers are coming to grips with back-end design problems is even more dramatically illustrated by the choice of one giant turbine per reactor for Sizewell (*6*). Bled steam is to be used to reduce exhaust wetness and the last row of blades will be the longest yet manufactured.

Fuel elements Aerodynamic trouble with the fuel elements for Bradwell and Berkeley was reported just before production was due to commence. It suggests that the extended surfaces may have been extended a little too far, making the fins and splitters too fragile. The problem is now whether they can be strengthened without affecting performance. Comparison may be made with the EDF-2 elements which seem much less delicate, and which the French claim to have better heat transfer properties.

The trouble with flutter is said to have been observed in elements loaded into the Calder reactors. Does this mean that the prototypes were not tested under full gas flow conditions before being run in an expensive in-pile experiment?

Another question has remained unanswered this year concerning hollow fuel elements. This feature is said to have been crucial in winning the Tokai-Mura contract and GEC are thought to have based their latest offer to the CEGB on them. Yet in spite of the fact that the AEA must guarantee hollow elements for Japan, the CEGB still will not accept them.

The achievement of over 2000 MWd/t by some of the original Calder elements is extremely encouraging.



SOME ADVANCED LAYOUTS (Fig. 2)

(a) The Integral Nuclear Steam Generator. All ducting, valves and bellows have been eliminated and the reactor core and heat exchanger tubing are contained in the one pressure vessel. (From a paper by W. R. Wootton presented at the IAEA Conf. Vienna 1960) (b) The Low Pressure Reactor. Highly simplified layout which is practicable if the gas pressure is reduced (Ref 15) (c) Underground reactor. The idea proposed in Sweden. The rock or lithostatic ground pressure, allows a thin flexible pressure vessel to be used. Containment is excellent—and the reactor is easily disposed of at the end of its economic life. (Ref P/2419, Geneva Conf., 1958)

Advanced gas cooled reactors

The AGR Considerable design information is now available on the Windscale AGR (*7*) which incorporates a great deal of fine engineering particularly in the compactness of the layout. Unfortunately, good construction progress is being overshadowed by gathering gloom about the economics. There has been an almost complete failure to develop satisfactory beryllium cladding, and with stainless steel cans the prospective generation costs hardly justify the expense of developing the system.

The construction of the elaborate hot testing facility Hero in parallel with the AGR prototype indicates that a need was felt to check the core kinetics at zero power, in particular the moderator and fuel temperature coefficients. However, the timetable of the two facilities suggests that there would be very little time available to apply the results of the Hero experiments to the AGR—another example of the difficulties of telescoped development.

The HTGR A race is now on between OEEC's 'Dragon' high temperature gas cooled reactor at Winfrith (*8*) and General Dynamic's HTGR at Peach Bottom, Pa. (*9*). Both systems are fundamentally the same; very high temperature helium circulates through an all-graphite core and fission products are vented continuously from the centre of the fuel elements. International cooperation is laudable but cumbersome and Dragon was slow to start while Peach Bottom was accepted for sponsorship by the USAEC in record time; progress is now roughly parallel on the two systems. High burnup and discard of spent fuel elements without reprocessing is a possibility, as well as the obvious advantages of a high temperature cycle. Nevertheless, the use of helium and enriched uranium presents procurement problems for Europe.

Water cooled reactors

The year has seen a slight shift in the relative prospects of the pressurized and boiling water reactors. A year ago, following the sucessful completion of Dresden, and the choice of a BWR in Italy (SENN) and Germany (Kahl), the BWR seemed clearly in the lead. This year an order has been placed for the largest water cooled reactor in the world, a 210 MWe PWR to be built at Givet, France, and the Yankee station has been successfully commissioned; while a serious design change of the SENN fuel element, leading to increased running costs, has been announced.

Construction progress The small BWR station at Kahl-on-Main, the first privately financed nuclear power plant in Europe and almost entirely German built, has been commissioned on programme. Systems of this size and type must now be a serious competitor in the small reactor field. The SENN plant on the Garigliano river has advanced to the stage of containment sphere construction. The pressure vessel is being built entirely by Italian industry, including the steel, and the methods used seem to be in advance of those in the USA. The cylindrical section is built up from three forged rings, and the greater part of the domed ends are formed from a single ingot instead of being built up from plates (*10*).

Design development The main target of BWR development is integral nuclear superheating and two prototypes are under construction at Sioux Falls (62 MWe) and in Puerto Rico (16 MWe). Successful superheating raises efficiency and lowers capital costs but aggravates the basic BWR dilemma—what degree of fuel element failure can be tolerated without fouling up the system?

The PWR only recently seemed to be in a state of opulent stagnation with the leading American manufacturers preoccupied with a giant naval programme. Now there is the possibility of a considerable advance in industrial reactors by a technique which attacks simultaneously two PWR problems. One of these is how to insert sufficient control to hold down enough reactivity to allow long burnups without reloading. The high system pressure limits the number of control rods which may be conveniently installed and liquid or burnable poisons have been used in the past. The other problem is how to improve the bad flux form factor. Babcock & Wilcox now propose the Spectral Shift Control Reactor (SSCR) in which the coolant is mostly heavy water at start-up. Poorer moderating characteristic pushes the neutron spectrum up into the epithermal range so that more neutrons are absorbed by fertile material rather than by fissile. As burnup proceeds, the heavy water is gradually replaced by light water and reactivity is added as the conversion ratio is reduced. The use of an external blanket greatly improves the power distribution across the core (*11*).

Heavy water There are signs that interest is being taken by the USAEC in heavy water and that greater attention is being paid to neutron economy in spite of the availability of U-235, which has caused in the past a somewhat cavalier attitude towards fuel costs. The most advanced design study at present being performed in the USA associates D_2O with gas cooling.

The Canadians continue to present a confident attitude about their programme and the future of natural uranium with heavy water moderation. In this they are joined by Swedish authorities but the two countries are progressing very slowly with comparatively limited resources. In Canada the goal of 1 mill/kWh fuel cost is still spoken of with confidence and no credit for plutonium is assumed (*12*).

After another year the AEA do not seem to have decided whether or not to develop the Steam Cooled Heavy Water Moderated Reactor.

Organic moderated reactors

Still long on promise but short on practical experience, the OMR has yet to find a champion willing to build a large scale prototype. With the collapse of the Stuttgart project, the station at Piqua (Ohio) of only 12 MWe capacity still remains the largest under construction. A further small experiment with an improved core has been approved by the USAEC. Hopeful design studies proceed as actively as ever in Britain, as well as in Italy, Germany, and (with D_2O moderation) in Spain and Canada.

In spite of the optimism of its protagonists, the OMR did not appear as the lowest cost system in the recent USAEC design study. The undoubted engineering advantages of a low system pressure and a non-corrosive coolant seem to be outweighed by problems of fuel design. Uranium metal, oxide and carbide have been proposed as fuel; the most promising can material, SAP (sintered aluminium powder) needs a great deal of development and has some problems like those of beryllium.

Other systems

Rather surprisingly interest has revived in the sodium graphite reactor as the Hallam 75 MWe plant nears completion, and its manufacturers are obviously recovering some of the confidence lost when the AEC experiment ran into difficulties. Apart from the high temperature advantages of this system, it is obviously a useful way of gaining experience of liquid metal cooling if a country's long-term programme includes fast reactors.

There have been no startling announcements from Dounreay during the year but a valuable and frank symposium on the experiment was presented in London during December (*13*). Many problems have been met in the handling of the NaK coolant and no appreciable power level has been reached a year after criticality. Meanwhile in the USA the Enrico Fermi plant is in serious trouble with severe allegations levelled at its safety. Certainly from the slowness with which the Dounreay experiment has been carried out it seems highly unlikely that a fast reactor could have been built as just another commercial plant.

Fuel cycles

A leading American physicist has suggested that bred U-233 is twice as valuable as reactor-grade plutonium and that to quote equal prices for both is unrealistic (*14*). Certainly there has been a marked increase in the use of thorium in the USA during the year. Many of the latest prototypes including the SSCR and the HTGR are being built with thorium blankets. Is this due to a growing evidence that there are insuperable problems connected with the use of plutonium as a fuel? The Americans are now making a determined effort to find the answer to this question as their Plutonium Recycle Test Reactor will be fuelled with high burnup Pu by 1962. The fantastic cross-sections of mixed isotope plutonium makes theoretical production impossible and results obtained from one reactor experiment are not necessarily true for another system.

One result of these tests could be that a realistic figure will be put to the price of plutonium. The long-term stability of British and American buy-back prices has been questioned by many economists, and it is significant that many designers are now hoping to irradiate fuel to the limit and then discard it, or at least store it until its potential use in fast reactors is known.

It is also becoming clear that the last word has not yet been spoken on natural uranium. The free market price of the material makes it most attractive to countries who do not wish to be tied to a single supplier. Up to

now, however, no natural uranium power reactor has been available in sizes much less than 100 MWe. At the time Calder Hall was designed its uranium loading of 130 tons was thought to be close to the lower limit at which a gas/graphite reactor would remain critical when hot. A recent paper by Strickland and Rudd (*15*) suggests that with present techniques 60 tons of natural uranium can provide enough reactivity for a long burnup and that a 30 MWe reactor could be built very cheaply with existing technology. If this is true, then a prototype should be put in hand without delay, as the market for a reactor combining natural uranium with a small output is considerable.

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2 Nucleonic instrumentation

by D. TAYLOR, M.Sc., Ph.D., M.I.E.E., Director, Plessey Nucleonics Ltd and Hagen Controls Ltd

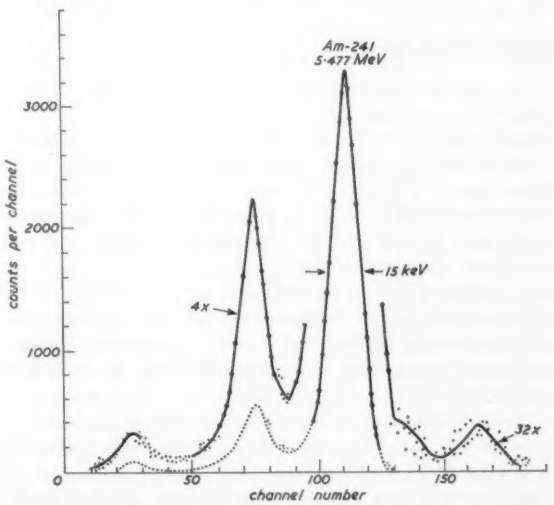
MANY OF THE TRENDS noted in last year's review have been maintained but, in addition, there have been a number of more spectacular developments which could have a significant effect on future instrumentation—semiconductor devices, for instance, are replacing thermionic valves on an increasing scale to allow reduction in power consumption and improvements in reliability. On the other hand, semi-conductor devices are now finding many applications to provide improved performance, as reported recently at Stockholm (*1*).

Radiation and particle detectors

One important development in the past 12 months has been the production of neutron-sensitive detectors for reactor control and other purposes, capable of operating at high temperatures. These were reported on by Gray (*2*), but with fission chamber detectors, the paper by Abson, Loosemore and Salmon, presented at the recent Stockholm Conference (*3*), should be singled out. The authors point out that both d.c. and pulse-type chambers are operated in conditions where ionization collection efficiency approaches 100%. In these conditions, the observed response (i.e. mean current or charge per ionizing event) is insensitive to variations of such parameters as recombination coefficient and drift velocities of the charge carriers. The detectors are capable of a much greater stability and reliability of operation over a wide temperature range than other types of detectors.

Scintillation counters are being used on an increasing scale. As reported by Owen (*4*) they have become one of the most widely applied forms of radiation detectors as they can be used to provide, with high efficiency and a considerable degree of precision, information on the time of arrival, energy and nature of the detected incident particle. Scintillation Track Imaging Systems which provide additional information on the position of the particles are also becoming available (*4*).

Plastic scintillators have been used for some years and their use is now increasing. This is because the decay times of the corresponding light pulses are several hundred times shorter in plastic than in, say, sodium iodide phosphors, which is an important consideration in coincidence measurements and counting at very high rates. Machining plastics to any size or shape is possible without the problem (*5*) of permanent enclosure of the phosphor in an airtight enclosure. Another attendant advantage is that air-equivalent response can be obtained with a plastic over a wide photonuclear energy range. In the past, the absence of total-absorption pulses when gamma-rays are incident on plastic phosphors has limited their application, but re cently Hine and Cardaselli (*5*) have studied this subject. They conclude that the two fundamental causes are that the photoelectric absorption in plastic is very small compared with sodium iodide and that there is difficulty in collecting the light produced by gamma-ray absorption in plastic scintillators. They also think that conical scintillators of proper size reflected with aluminium foil or aluminium oxide produce total absorption pulses with low energy photons and their methods will no doubt have a wide application.



Resolution of fine structure of Am-241 using a shallow diffused pn junction, expanded scales give peak details (Fig. 1)

Solid state detectors are now showing spectacular improvement. There is still the difficulty of guaranteeing reproduceable characteristics but the successful development of germanium and silicon junction transistors is renewing interest in this field. In some instances, the small size of the semi-conductor is an advantage but a large sensitive area is sometimes essential. This calls either for the production of large areas of semi-conducting material, which may be difficult or impossible, or the operation of a number of small detectors connected in parallel.

Diffused silicon junctions are now being used as particle detectors. The charge is collected in a few nanoseconds and its magnitude is directly proportional to the energy dissipated in the depletion layer of the semi-conductor. Together with the rapid response, such depletion layer detectors are robust, of small size, have high spatial resolution and for alpha-particles. The energy resolution can be better than 1%, Fig. 1, for example, shows the remarkable resolution in the fine structure of Am-241 (*6*).

In addition, by using high resistivity silicon, Williams (*7*) has reported that a nuclear particle detector of transistor configuration can be produced giving current magnifications of from 300 to 1500 with a better signal/noise ratio than a single *pn* junction.

There have also been developments in this field for gamma-ray measurements. Donovan (*8*) has studied silicon *pn* junctions with depletion layers about 0·8 mm thick, and has found that gamma-photons which produce photoelectrons whose range in silicon is less than this thickness, can be detected with an energy resolution of about 6·5 keV. Measurements of the effect of gamma radiation on silicon *pn* junctions, show that the energy resolution deteriorates with increasing dose rate, but the change is negligible for the usual health physics levels though serious in the region of 10^5 r/h.

Cadmium sulphide gamma-detectors are also becoming more interesting. These were reported on recently by Smith and Kelly (*9*); at the recent International Instruments and Measurements Exhibition (see *Nuclear Power*, November 1960, p. 107) AERE exhibited a number of simple measuring instruments using these detectors. High sensitivity without valve amplification is possible.

Measuring techniques

As reported in last year's review (*10*), some organic phosphors produce longer output light pulses from the recoil protons due to fast neutrons than from Compton electrons due to gamma-radiation. Various circuits which make use of this property and discriminate between the two types of pulse shape in order to measure fast neutron dose rates in the presence of gamma-radiation (or vice versa) are discussed in the literature (*11, 12*). Gamma-ray discrimination factors of 5000 to 1 can be obtained under optimum conditions. Batchelor, *et al.* (*13*) have recently described improvements in the fast neutron time of flight technique, using pulse shape discrimination in an organic phosphor.

At one time (*14*), it was thought that a fast neutron monitor for radiation monitoring might be built, using this principle, since fast neutron detection efficiencies of the order of 10% are possible with gamma efficiencies less than 0·007%. However, it has now been found (*15*) that gamma ray rejection of 5000:1 cannot be obtained over a wide range of dose rate and other methods have had to be considered.

One of the most significant trends in recent years has been the widespread application of gamma spectroscopy not only as a laboratory technique but also in portable instruments. By this means, the dose rate contributed by a specific isotope, in some cases even in the presence of larger backgrounds at other energies, becomes a possibility. Instruments of this type have been reported for monitoring Pu-239, U-235, I-131, etc., by monitoring the specific gamma-ray energy band but the advent of the silicon junction alpha detector is now allowing a similar range of instruments to be developed, based on alpha spectroscopy.

An interesting technique is that reported by Sill and Flygare (*16*) in which sample air is drawn continuously through a cartridge of activated charcoal in the central well of a sodium iodide scintillator. With a counting rate-meter and chart recorder, the activity built up on the cartridge can be followed as a function of time. With a sample taken at the rate of 1 ft^3/min for an hour, the limit of detection is $1{\cdot}3 \times 10^{-11} \mu c$/ml.

A health physics problem is the monitoring of atmospheric air for plutonium. This has been discussed (*17*) by the present writer, when it was suggested that an excellent method would be to collect the plutonium particles by using an impactor (thereby allowing some separation of the plutonium particles from the radon and thoron decay products) and examining the collected sample, using scintillation counters employing a coincidence technique to discriminate further between the alpha-emissions from the Pu-239 and the emissions from the radon and thoron decay products. AWRE have demonstrated (see *Nuclear Power*, November 1960, p. 107) the advantages to be gained by using the impactor technique, in allowing improved sensitivity. However, the use of the technique only allows discrimination for plutonium particles of about one micron size, which are more readily collected, than the smaller decay products of radon and thoron.

Multi-channel Pulse-Amplitude Analysers continue to be used on an increasing scale, but new techniques are beginning to be used. One interesting technique is to use a tape to record the results of an experiment and then replay the tape into a pulse amplitude analyser to analyse the spectral information. The advantage of this is that a range of tape recording equipment can be used and, as the tapes can be run through at increased speed, more economical use can be made of a single relatively expensive multi-channel analyser. It is also possible, as has been explained by Bird, Waters and Wells (*18*), to use the tape technique for performing relatively complicated measurements, which would probably be impossible by conventional techniques.

Reactor instrumentation

Reactor instrumentation techniques have not changed greatly in the past year. In all cases, however, transistorized instruments are being increasingly used and data processing systems are beginning to be introduced experimentally on several plants. A good summary of recent trends in this subject was given at the recent I and M Conference (see *Nuclear Power*, November 1960, p. 104 and reference (*19*)).

In the past, safety circuits using magnetic relays have been widely used. However, there has been a tendency away from magnetic relays and in favour of transistors

but more recently, it has been demonstrated that advantages can be gained in flexibility, as well as small size and low power consumptions, by employing ferrite cores. An experimental system using wound toroidal ferrite cores with transistor drive and 'read' circuits has been demonstrated by Whyard at AEE, Winfrith.

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3 Process chemistry

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LAST YEAR'S SURVEY (*1*) pointed out that there were few highlights to report in Process Chemistry in 1959 and this comment might also apply to the year 1960. Even so, there have been a number of interesting developments which are largely related to the need for processing power reactor fuels. This was forecast in the 1959 review (*1*) and it is interesting to look at United States efforts in this direction. Thus, Stevenson (*2*) has described how the processing of US power reactor fuel can be met by extending the capacity of the Hanford, Idaho, Oak Ridge and Savannah River plants. The fuel from some 20 power reactors was assigned to these plants and it was concluded that each plant would require expansion of its facilities; such expansion was, in fact, planned.

Private reprocessing plant

In January, however, the USAEC announced it would hold up this expansion until the six-company Industrial Reprocessing Group completed a study of the possibility of industry taking over the processing of fuel from private power reactors. This Group has been formed by the Davison Chemical Division, W. R. Grace & Co., with the support of a number of utilities actually building power reactors, and the terms of reference are to study the technical and economic aspects of the design, building and operation of a solvent extraction unit using the Purex or the Redox process. The Power Utilities say they are prepared to pay up to 20% more to have their fuel processed privately rather than in USAEC plant. It is apparent that private industry feels that in the long run, they can make such plant economically more successful than existing USAEC controlled plant.

An important report (*3*), issued in January, contains papers presented at the Hanford Conference on Chemical Processing of Irradiated Fuels in which recent developments in each of the four main US plants are described. An interesting feature is the emphasis on 'head-end' feed preparation. If the wide variety of fuels (e.g. uranium at all degrees of enrichment, uranium alloys, oxides and carbides, plutonium etc) and cans (e.g. aluminium, magnox, stainless steel, zircaloy, zirconium etc.) which are used or proposed in power reactors are considered in terms of fuel reprocessing, it can be appreciated that it will not be feasible to build separate plant for each fuel. It is, therefore, preferable to attempt standardization of processing methods after the fuel has been got into solution and perhaps undergone a suitable preliminary stage to suit it to the standard plant.

Windscale second plant

Construction of the Windscale second plant continues. The process has now been described by Tuohy (*3*) and Saddington (*4*), and, as was suggested in last year's report, TBP (actually 20% tributyl phosphate in kerosene) is the solvent and box mixer-settlers are to be used in place of the gravity-feed columns of the existing Windscale process. This second plant is designed to deal with all fuel from the CEGB reactors, whereas the first plant was designed for the Windscale reactors, but is now used for fuel from Calder and Chapelcross reactors. There is no intention that industry should process irradiated fuels in this country. It seems unfortunate that the two UK firms who offer to build nuclear chemical plant abroad should not have been given more opportunity to assist in the building of the new Windscale plant.

Marcoule

France is to start building next year a second plutonium separation plant (at Jobourg) to process fuel from the Electricité de France (EDF) reactors. Presumably this will be similar to the Marcoule plant (using TBP) which processes the G1, G2, and G3 reactor fuels.

Eurochemic plant

The Eurochemic Plant of OEEC at Mol, Belgium, is designed to process 350 kg/day of natural uranium or 250 kg/day of up to 5% enriched uranium and completion is planned for 1963. Detilleux (*3*) has outlined the process which is based on the Purex process. Final plutonium purification was first to be on anion exchange resins, although more recently use of an amine solvent has been suggested. Long chain tertiary amines are useful as specific extractants for plutonium but, although they have been studied in several laboratories, there is little pub-

lished data to indicate their real capabilities. It is interesting to see that anion exchange resins have been considered for Eurochemic. These have been used to some extent in the USA for final plutonium purification but are not used in the UK. They have desirable properties both for concentration and purification of plutonium, and, although doubt has been expressed on their radiation stability, recent work (5) would indicate that their stability is quite sufficient for most processing plant requirements.

Fuel processing in India

The Indian AEC is now operating, at Trombay, a small plant to extract and purify uranium from the ore and convert to the metal. The metal is then fabricated into NRX-type fuel assemblies for the CIR reactor. This Indian designed and built plant produces 30 tons/a uranium metal and it is planned to increase production to 100 tons/a. Two Indian fuel elements have already withstood irradiation up to 1500 MWd/t in the NRX reactor. India is also building a small irradiated fuel reprocessing plant at Trombay for the CIR fuel elements. Initially this plant, which is batch operated and is based on TBP extraction (presumably a Purex process) followed by an ion exchange step for final plutonium purification also includes a plutonium metal conversion plant. This will deal with the CIR natural uranium fuel but the process is designed to cope with enriched uranium fuel in the future, if necessary.

Uranium-235 separation

There has been much discussion about prospects for uranium-235 separation by gas centrifugation. This technique has been studied mainly in W. Germany, the Netherlands and the University of Virginia in the United States in recent years, although Westinghouse Electric Corp. carried out design and pilot plant studies in the early Manhattan Project days (6). It now seems certain that small quantities of enriched uranium can be obtained without the necessity of building enormous gaseous diffusion plants. This possibility has caused concern and the US State Department has now persuaded the W. German Government to declare all its work on centrifuge technology secret.

The nozzle technique for separation of uranium-235, which was described at Geneva (1958) by Becker is being studied in the USA by Levoy (7). It is claimed that although costs are high, a more reliable process and higher separation per stage can be achieved. France has now decided to build a gaseous diffusion plant at Pierrelatte 15 miles north of Marcoule with a capacity of 350 tons/a.

Reactor chemistry

It is appropriate to draw attention to a new branch of Nuclear Technology which is arousing considerable interest amongst chemical engineers and chemists. This is sometimes referred to as Reactor Chemistry and covers chemical topics related to reactor operation and safety e.g. corrosion within the reactor between fuel and can and can and coolant, stability of moderator and coolant at high neutron and gamma fluxes and temperatures, precautions against release of radioactivity in the case of reactor failure etc. The spread of iodine-131 after the failure of the Windscale reactor has resulted in extensive programmes of research into the efficient 'filtration' of iodine-131 from reactor cooling circuits and incorporation of such equipment into UK civil reactors.

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4 Applied irradiation

by S. JEFFERSON, B.Sc.(Eng.), A.C.G.I., Head of Radiation Branch, Isotope Research Division, AERE, Wantage

THE PAST YEAR has seen two large gamma radiation plants come into regular operation — the Package Irradiation Plant at the UKAEA's Wantage Research Laboratory and the Goat Hair Plant of the Westminster Carpet Company, Melbourne, Australia, which has formed a subsidiary company, Gamma Sterilization Proprietary, to extend the scope of its operation to other products.

The Package Irradiation Plant (PIP) was designed to provide irradiated material for large-scale experiments and to enable interested manufacturers and hospitals to carry out marketing and clinical trials. The PIP was designed to have a high degree of versatility of dose and package density, but a standard size of package; the dose is determined by the speed at which packages travel through the plant. For instance, a sterilizing dose of 2½ megarads is given in about 20 h with the present strength of the source (150,000 curies). The shielding is designed for 500,000 c, and this strength of source would reduce the time for a sterilizing dose to about 6 h. Since the irradiation chamber holds about 100 packages, a total irradiation time of 20 h corresponds to the production of one package every 12 min.

The capacity of the plant is nearly all let out to industry. The charges are based on the number of packages because the plant output is determined by volume and not by density. The permissible density range is from 5 lb per package to 40 lb per package. For sterilizing packages of high density in quantities of 500 the cost is thus about 4*d*/lb and for the lowest density 2*s* 9*d*/lb. On account of the wide ranges of weight and dose that were demanded, the efficiency of utilization of the gamma radiation had to suffer and a plant specifically designed for a sterilizing dose could be operated at higher efficiency and hence at lower cost.

The plant built near Melbourne, Australia, is the first industrial sterilization plant using gamma rays. It started operation with 150,000 c supplied by the Radiochemical Centre, Amersham, and has since had its strength increased to 500,000 c from the same organization. The basic design of the plant was supplied by the UKAEA, the detail design and actual building being performed by local contractors. All goat hair imported into Australia (and into the UK) must be sterilized against anthrax infection and some of the goat hair from the Middle East in fact comes to Liverpool for chemical treatment at the Government Wool Disinfection Station before onward shipment to Australia. The Chairman of the Westminster Carpet Company, Mr Jack Dews, learnt of the possibility of sterilizing goat hair by gamma rays from the Superintendent of the Liverpool unit who had been carrying out some investigations in conjunction with Wantage Research Laboratory.

The main advantage of gamma radiation sterilization of goat hair is that the unbroken bales can be treated. In other processes the bales must first be broken down, a procedure which results in hazard from contaminated dust.

In the UK the main industrial interest in gamma irradiation is for sterilizing disposable medical equipment. The feasibility of the system has been established by small batches processed in the fuel element pond at Harwell. The outstanding features of gamma sterilization are: room temperature working, complete penetration and absolute reliability. A sterilizing dose of 2·5 megarads is equivalent to 25 joules (6 calories) per gramme, i.e. if the irradiated material had a specific heat of unity the total temperature rise would be about 6 deg C. Consequently the method can be used to sterilize material that could not stand heat treatment. No method of sterilization imparts any immunity against further infection and so the materials to be processed must be sealed against contamination by bacteria or viruses; the penetration power of gamma rays makes the complete sealing of the product a feasible operation.

Many medical items are now made so cheaply from thermo-plastic extrusions that it is cheaper to use them once only rather than spend time in cleaning and resealing and sterilizing; all items which use lengths of tubing are particularly suitable for manufacture in thermoplastic materials. Scalpel blades can be sterilized without any fear of spoiling the cutting edge and the strength of sutures (cat-gut) is maintained at a high level by this treatment. Articles made from rubber such as catheters and surgical gloves can also be processed.

Food irradiation

Food irradiation is still handicapped by unpleasant off-odours when complete sterilization is attempted. However, if some of the products are stored in the presence of activated charcoal, the unwanted effects are reduced and all but completely eliminated if the food is then cooked. By using this technique it is possible to can high quality meat which would deteriorate in texture if given the heat treatment associated with normal canning processes. The meat is canned together with a small packet of activated charcoal. It is then given an irradiation dose of 4·8 megarads, which will eliminate *Clostridium botulinum*, and a light heat treatment to inactivate the enzymes. The can may then be stored for two or more years at room temperature and when opened and the cooking process completed, the product compares favourably with freshly cooked meat.

The American Quartermaster Corps food irradiation programme was under heavy fire about a year ago but seems to have emerged surprisingly unscathed, apart from the low dose treatments having been split off to form a separate American AEC programme. Workers in this field in the UK have always tended to favour pasteurizing treatments rather than complete sterilization. The international conference run by the FAO at Harwell in November 1958, recommended as one of the most promising lines, the elimination of salmonellae in frozen whole egg; this work has been continued and during the year has been extended to salmonellae in desiccated coconut and animal feeding stuffs. Salmonellae infection in man and animals is relatively common, and a great deal of work is being done to trace the infection. A dose of about 0·5 megarads is adequate to deal with the most resistant type of salmonella, and results in a generally acceptable product. Treatment of frozen whole egg is well suited to gamma irradiation because the process can be carried out without raising the temperature more than a few deg C, i.e. without unfreezing the egg.

The pasteurizing dose of 0·8 megarads applied to freshly eviscerated chickens has been shown to increase their refrigeration life (at 1 °C) from 10 days to 18 days, and the quality of the birds is maintained.

Studies of the disinfection of grain and rice have shown some possibilities of applying the technique in Australia. The seasonal nature of the process and the high handling rates seem to suit high output electrical machines. The output power is certainly available and the problem which remains is the deposition of the dose uniformly throughout the product at handling rates up to 200 ton/h. The seasonal nature of the load favours machines because the running cost is more closely related to the number of hours of operation, whereas Cobalt-60 continues to decay whether it is used or not.

In the chemical field, graft polymerization has been further developed as a means of depositing thin conducting films or surface treatments to improve at dyeability. The dose required to crosslink rubber has been reduced by a factor of ten but still further improvement is required before the process becomes economically attractive. In general, there is a swing to basic research to study chemical effects of radiation and a few short-term projects are likely to show an economic return.

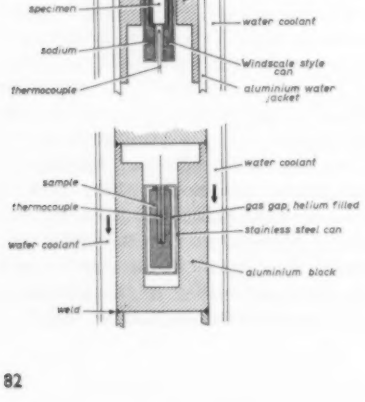
The use of prestressed polythene sheet for food wrapping has revived interest in an old phenomenon. Polyethylene is crosslinked with a dose of five or more megarads and then stretched at softening temperature and cooled in the extended condition. If reheated the stresses are relieved with a shrinking to the original dimension. If the prestressed film is used to wrap dressed chicken, the wrapping can be tightened by a simple heat flash to the condition which gives the customer a good view of the bird. The crosslinking of the polyethylene film can be achieved either by electrons focused on the moving film, or by subjecting complete rolls to gamma irradiation. Many tens of miles of polyethylene tubing have been subjected to gamma radiation from spent fuel elements in the Harwell pond. The tubing is principally used for electrical sleeving and the treatment reduces the local melting of the insulation when soldered joints are made to the conductor.

The previous article discussed development of irradiation techniques used at Windscale. The experimental programme was transferred from Windscale to AERE when Dido and Pluto came into service and new methods had to be adopted

Irradiation techniques for fissile materials—2

by O. S. PLAIL, A.M.I.Mech.E., Group Leader, Irradiation Branch, Metallurgy Division, AERE, Harwell

IN THE WINDSCALE experiments, the samples had been highly enriched to give fairly rapid burnup rates but were small in size to keep the ratio of surface flux/centre flux at a reasonable figure. Although the research programme had the same overall objectives, with the considerably higher available neutron fluxes in the new reactors, alterations to the specimen parameters were advisable. In addition, these higher fluxes raised more severe heat transfer problems. In Dido, with the increased thermal neutron flux (8×10^{13} n/cm²/s is typical) either a considerably increased burnup rate could be achieved using samples similar to those previously used, or, using roughly the same burnup rate (i.e. the same rating), the sample size could be increased with a corresponding decrease in enrichment. The latter alternative was chosen. As previously discussed, the rapid burnup of highly enriched samples would have speeded the overall irradiation by a small amount but introducing much larger specimens gave considerable advantages in the post irradiation examination compared with the very small buttons previously used. Therefore, specimen sizes about 0·2 in dia. $\times$ 0·5 in long were adopted and enriched so that the heat output of each specimen was about 500 W maximum. Obviously, by changing both enrichment and size, the heat output may be varied considerably; but the figure of 500 W provided a good starting point for subsequent design and for planning the experimental programme.



Schematic illustration of two types of thermal barrier experiments (Fig. 1)

Because it came into operation before Pluto, work was concentrated on Dido. The experimental facilities consist, in the main, of vertical experimental aluminium thimbles, either 2 in, 4 in, or 6 in dia situated in the D_2O or the graphite reflectors. The highest fluxes (10^{14}n/cm²/s thermal) are in the 2 in thimbles close to the core; the 6 in and 4 in thimbles in the D_2O have rather lower flux levels ($3–8 \times 10^{13}$n/cm²/s thermal) and the graphite reflector holes have fluxes similar to those of the Windscale reactors (only 4 in and 6 in thimbles in the D_2O were chosen for this work). As with all small cored research reactors, there is a fairly severe flux gradient in these experimental thimbles which makes planning experimental programmes difficult. Following Windscale practice, as many samples as possible were accommodated in each rig and it was considered essential that each specimen should be operated under controlled conditions with independent temperature control and measurement, temperature ranges between 200°C and 800°C being required. Arbitrary but intuitive choice of specimen numbers gave five capsules for irradiation in a 4 V rig and 10 for a 6 V.

POSSIBLE COOLANT SYSTEMS

The specimen parameters chosen resulted in surface heat ratings of some 200 W/cm² compared with about 20–30 in earlier experiments so that the method of heat loss by convection from a small capsule was not attractive. Three methods of cooling were considered for the new rigs. Firstly, pumped liquid metal coolant (sodium or sodium/potassium alloy) was at one time thought the most likely method. But consideration of the very complicated pumps and gear required, together with the considerable reactor hazard led to its rejection. Gas cooling was considered but also rejected for a variety of reasons.

The other alternative was water cooling and in fact an auxiliary light water cooled system had been designed into both the Dido and Pluto reactors. The use of water as a direct coolant was not feasible because operation of the specimens at the elevated temperatures required would have been impossible. Even if a pressurized circuit

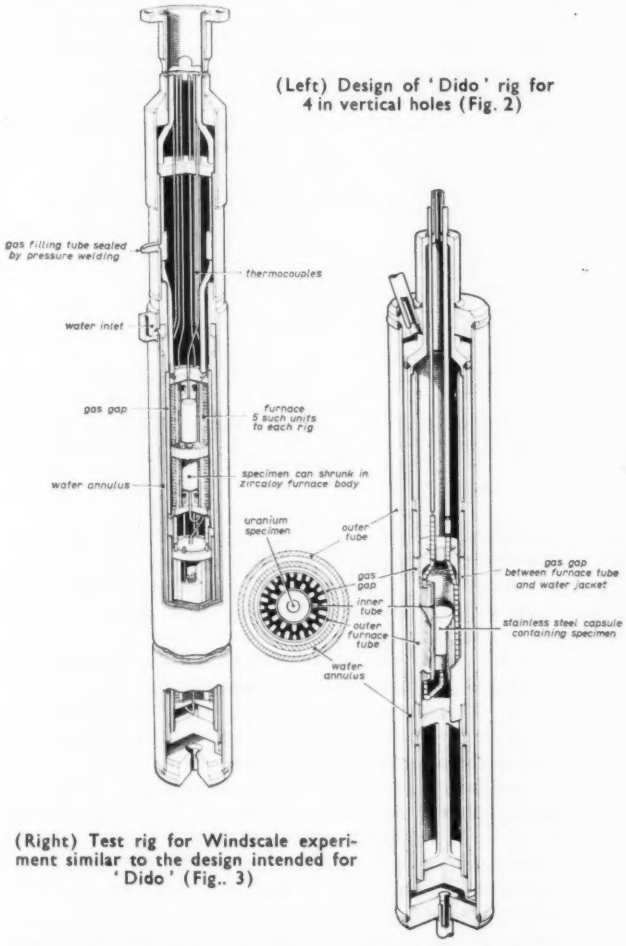
were used, the practical limit would have been about 300–350°C. However, the use of the auxiliary water circuits on these reactors would avoid the expensive installation costs of new cooling systems. In many ways the handling of water and its containment presented fewer difficulties than either gas or liquid metal systems. A serious hazard was the possible escape of the light water into the heavier water moderator with the consequent serious financial loss. Apart from this, the main problem was that of using light water cooling at normal pressures and temperatures for cooling high temperature (800°C) specimens whilst maintaining good temperature control.

PRELIMINARY WORK

This problem had, to a certain extent, been met during earlier work the Metallurgy Division had been carrying out using water cooling for some high temperature experiment. The difficulties of maintaining these temperatures had been overcome by inserting a thermal barrier of known dimensions and thermal conductivity between the specimens and the coolant. Two forms of thermal barrier had been tried; a carefully machined former of zirconium so that a known thermal gradient existed between the specimen and the coolant and a helium gas barrier. The first method was used in combination with a furnace to give temperature control; the zirconium former was dimensioned so that under the maximum fissile heat output expected from the specimen, the temperature would operate below that required experimentally. This was in accordance with standard practice of overcooling combined with auxiliary heating adopted in the Windscale work. The second was an attempt to see if this method could be adopted for in-pile use. No furnace was used and helium was chosen as the barrier gas because it has the highest thermal conductivity of the inert gases and allowed larger gaps to be used. The two experiments gave valuable data both in the preliminary laboratory mock up stages and during the irradiation experiments; they showed that temperature control by means of a pre-determined thermal barrier had considerable promise. Figure 1 shows diagrammatically these two experiments. The use of ceramic formers had been considered but the difficulty of accurate machining and their fragility caused their rejection for use as thermal barriers.

The experience gained and the disadvantages of other methods of heat removal led to the use of light water cooling coupled with the insertion of a thermal barrier in the heat transfer path for the fissile irradiations in both Dido and Pluto. The gas gap method was chosen in preference to the solid conductor as it involved fewer mechanical problems. By suitable design of capsule and furnace assembly to give a large external surface area and using helium, gas gaps up to 0·100 in wide could be used. Thus normal machining variations of say ± 0·001 in in the gas gap would not lead to serious discrepancies in heat transfer. The other factor that permitted these large gas gaps to be maintained was the use of very pure gas—one of the most important facts found in early experimental laboratory work was that even small traces of impurities could seriously affect results. This is perhaps not surprising when one considers the large differences in thermal conductivity of helium and the likely impurities but disregard of this fact can cause disappointing results.

The choice was further influenced by the operational conditions it was hoped to achieve. The elimination of as much thermal cycling as possible from many of the experiments was desirable and it was felt that if a fixed temperature datum could be achieved one variable would be eliminated and the task would be considerably eased. In other words, if the cold surface could be maintained under all reactor conditions the build up of temperature control could begin from this cold surface. Because the auxiliary cooling water did not vary by more than some 20–30 degC from reactor operating to reactor shutdown conditions it was eminently suitable for this purpose.



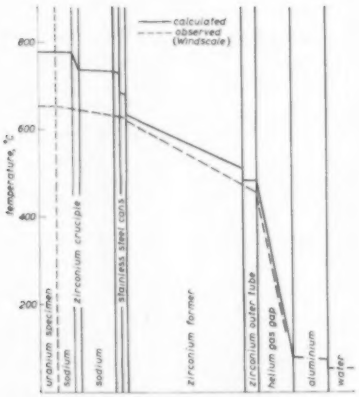
(Left) Design of 'Dido' rig for 4 in vertical holes (Fig. 2)

(Right) Test rig for Windscale experiment similar to the design intended for 'Dido' (Fig.. 3)

With the constant temperature surface from which to work, the next requirement was for constant heat transfer conditions and a constant heat input. This can be provided by using a furnace capable of delivering, under any condition, the total quantity of heat needed to maintain the planned thermal gradient across the gas gap. In other words, if during irradiation, the fissile heat is x W and the extra electrical energy of amount y W is required to maintain temperature, then to a first approximation the same quantity of heat would be required under shutdown conditions, and the furnace would have to be capable of delivering $(x + y)$ W in these circumstances. As with the Windscale experiments, the aim was to design heat transfer conditions so that when specimens were free running under fissile heat alone, the temperature was some 100 degC

or so lower than required experimentally; the planned temperature was achieved by using the electrical heater.

The first design, shown in Fig. 2 was for a rig to be irradiated in a 4-in vertical experimental facility in Dido. It consisted of an outer water jacket in which were inserted furnace assemblies carrying the specimens to be irradiated. Between the outside of the furnace and the water jacket was a helium filled gas gap. The furnace assembly itself consisted of a finned hafnium free zirconium former carrying furnace windings. In the centre of the former fitted the specimen can assembly, consisting of an inner sodium filled can surrounded by an outer can as used in the Windscale rigs. Two thermocouples for temperature control purposes were used, one entering from the top and one from the bottom of the capsule. The rig incorporated both types of thermal barrier previously tried but this was mainly because the furnace construction had to provide not only a convenient holder for the windings but also a positive heat transfer path; in fact, the rig design was based mainly on the use of a gas barrier.



Comparison of calculated and observed temperature gradients across the rig shown in Fig. 3, the heat flux is 500 W (Fig. 4)

A laboratory experiment incorporating a small furnace to simulate the specimen and using stainless steel in place of the zirconium (these two materials have about the same thermal conductivity) was constructed with suitably placed thermocouples to measure thermal gradients and in general thermal conductivity calculations were confirmed. It also demonstrated the very great care needed to obtain reproducible results. A rig was inserted into the Windscale reactor for a short trial period. This was similar to the design intended for Dido and is shown in Fig. 3. Again, by using extra thermocouples placed at convenient points in the rig, the thermal gradients were measured; these are shown in Fig. 4 together with predicted values. The results of these two experiments were so promising that the Dido rig was constructed and inserted into the reactor. Five specimen can assemblies were accommodated in this rig which gave very good service, staying in the reactor for some eight months during which time the furnaces worked reliably. The problem of bringing power cables and thermocouples to the respective furnaces was solved by threading them through the upper furnace assemblies. In practice this involved considerable difficulties during assembly.

NEW WATER JACKET DESIGN

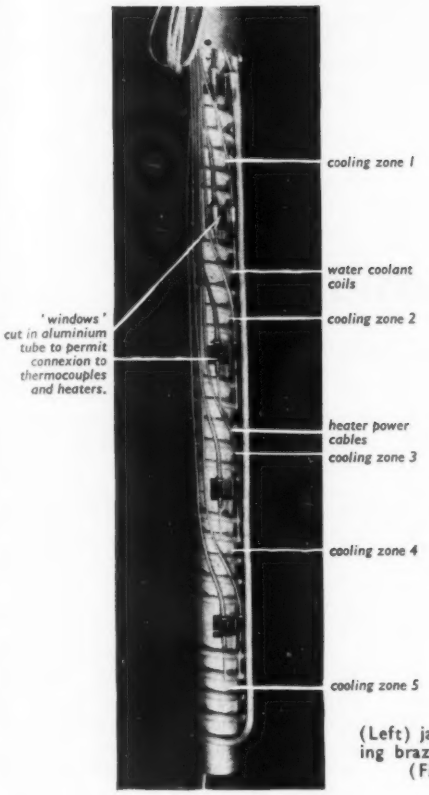
As a result of laboratory experiments, the new water jacket consisted of a single large diameter aluminium tube to which was brazed, in a series of coils, a small bore aluminium tube which the coolant passed through. The coils were grouped to form five distinct cooling zones and between each of these, gaps or windows were cut in the larger tube (Fig. 5). An outer jacket covering the water cooled tube completed the assembly. This jacket was required to retain the gas atmosphere in the rig. Each batch of coils was arranged to provide cooling for separate furnaces; the windows provided an easy method of bringing the furnace leads and thermocouples to the separate furnaces and capsule assemblies. Its introduction immediately eased the manufacture of the rigs and also permitted much easier assembly of the furnaces. The successful operation of the rigs depends largely on maintaining known heat transfer conditions and because the gas gap thermal barrier is rather narrow, accuracy and reproducibility are essential. Therefore the bore of the large diameter aluminium tube was plug drawn to size after brazing the water coils, giving both an accurate bore and a smooth surface finish. This basic design of water jacket has been used both for rigs in 2 in, 4in and 6 in dia. facilities in Dido; the 6-in rigs are two 4-in jackets side by side.

As with other rigs, these water jackets had to be attached to neutron shielding plugs and a typical plug is shown cut away in Fig. 6*b*. In all cases, adequate shielding equal to that of the reactor biological shielding has to be provided while still permitting heater and thermocouple cables to be taken from the reactor face to the furnace assemblies. This is achieved generally by having the hollow plug body, frequently of cast iron, filled with resin, iron shot and lead through which pass spiral service tube. Through these service tubes pass all the power cables, compensating leads for thermocouples, water tubes etc. In a 6-in rig there are some 60 thermocouples and 20 heater leads to be brought through as well as the water pipes. Mineral insulated cable is very largely used both for power cables and for compensating leads for thermocouples. The space left in the service tubes is finally filled with resin which also seals the inside of the rig from the outside atmosphere.

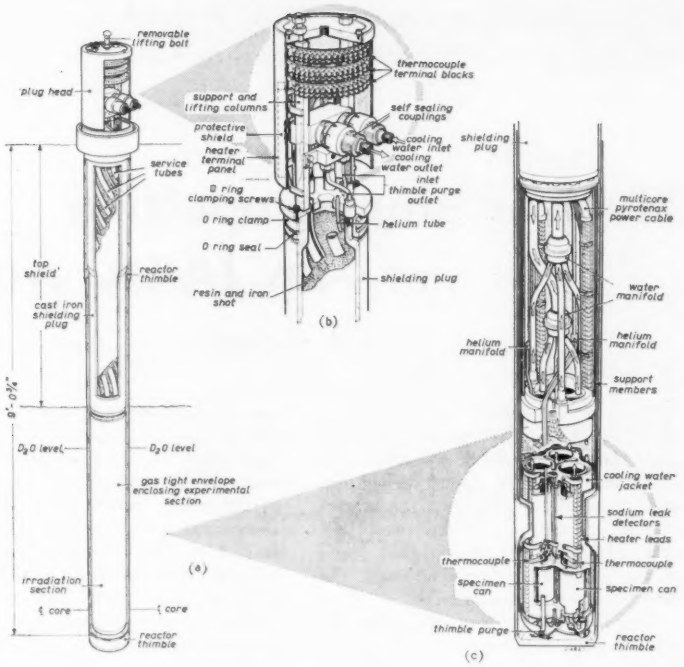
On the outside of the rig (Fig. 6*a*) is fitted an aluminium envelope which is sealed to the bottom of the shield plug. This outer casing being gas tight maintains the required gas atmosphere in the rig and acts as a barrier should there be a release of fission products from the capsule assembly. As a further safety measure, the plug is sealed into the thimble of the reactor by O-ring seals. The gas atmosphere maintained in the thimble is helium so that should there be a leak in the outer casing of the rig, there would be no danger of an unduly high temperature occurring in the capsule due to dilution of the rig atmosphere with a gas of low thermal conductivity. Maintaining a controlled purity gas atmosphere in these rigs has been a major problem. Figure 6*b*. shows the top of a typical shielding plug, to which are attached the terminals for the various leads; space is very limited and all connexions have to be made in a very small volume.

PLUTO RIG DESIGN

When the experimental programme was extended to include the Pluto a new rig design had to be considered. The experimental facilities used consist of 7 in vertical and horizontal aluminium thimbles in the D_2O moderator. The experiments planned were on samples considerably


cooling zone 1
water coolant coils
cooling zone 2
'windows' cut in aluminium tube to permit connexion to thermocouples and heaters.
heater power cables
cooling zone 3
cooling zone 4
cooling zone 5

(Left) jacket showing brazed on coils (Fig. 5)



Complete irradiation assembly (a); cut-away of plug head assembly (b); and irradiation section assembly showing trefoil water jacket (c) (Fig. 6)

larger than those irradiated in Dido with heat outputs of some 2 kW. Thus each furnace assembly rating should, if the practice of equal fission and electrical heat outputs be maintained, have been 4 kW to maintain temperature at shut down. This figure was considered rather excessive and a compromise figure of 3 kW was chosen for the Dido type rig already described. The heat output of one furnace position was limited to 1 kW and the quantity of water that it was possible to pass through the cooling coils with the pressure drop available was considered inadequate for the higher output. One of the parameters taken for Dido design had been that nucleate boiling should not occur in the water under conditions of full reactor power combined with the maximum electrical heat possible and assuming a furnace control gear fault. To achieve the higher coolant rates several schemes were discussed but the one finally chosen consisted of an extruded aluminium section in which the water channel was an integral part of the extrusion. This extruded section was shaped so that when three sections were welded together a trefoil water jacket resulted in which three furnace assemblies could be accommodated in one plane. Figure 6c shows a completed rig cut away to illustrate the completed trefoil. Nine furnace assemblies are normally accommodated in each of these rigs being arranged in three sets of three, giving a total heat output of some 27 kW. The same method of bringing the electrical leads to the furnace and capsule assemblies as on the Dido rigs was used. However, because of the rather odd shape of the water jacket a solid aluminium portion had to be left in the extrusion in which the windows could be machined (see Fig. 6c). Serious troubles were experienced during fabrication of these rigs because of distortion of the bores and a considerable manufacturing development programme had to be carried out. A later Pluto rig design incorporates the Dido type water jackets and the problem of adequate water supply is overcome by using individual water jackets for each furnace assembly.

Experience with a number of both the Dido and Pluto rigs have shown them to be reliable and versatile. So far no failures due to the water jackets have been experienced in the reactor. Their versatility stems from the fact that they are in effect coolant jackets into which a variety of different types of experiments can be fitted. Provided the test capsule conforms to the dimensional and heat output limits imposed by the rigs then an almost unlimited range of experiments can be carried out in addition to the capsule work for which they were designed. This use of a standard rig generally simplifies assembly and considerably reduces the amount of expensive design and development which would be required if all experiments were specially designed.

Summary

The choice of water coolant coupled with gas gaps in preference to either liquid metal or gas cooling for high temperature irradiation on fissile material has been of vital importance for the Metallurgy Division's irradiation programme. This concept, although basically simple, has required very considerable development, and the water jacket evolution described is only one aspect of the work. The next article will deal with other facets of this work including heaters, capsule design, out of pile testing, instrumentation etc.

Safe nuclear ships can and should be built now but more all round research is needed

Nuclear ship propulsion —an IAEA symposium

by R. ANSCOMB, M.I.N.A., M.I.Mar.E., Head of Marine Section, UKAEA, Risley

THE UK GAVE gave strong support to the IAEA Symposium on Nuclear Ship Propulsion. Next to the Italians, it had the largest delegation and, in addition, presented the largest number of papers. Furthermore it was clear from the discussion that some of the UK papers were amongst the most interesting presented.

The IAEA arrangements made for the advance reproduction of papers, simultaneous translation, and general servicing were extremely good. There were few occasions when delegates did not have copies of the papers to read before their actual presentation. It was also very satisfactory to note the successful steps which the IAEA had taken to obtain the collaboration of the International Maritime Consultative Organisation (IMCO) in organizing the Symposium.

International activities

The US papers dealt mainly with progress in the construction and testing and safety assessment of the nuclear installation in NS *Savannah* and with other design studies now being undertaken. Mr W. C. Ford of the US delegation made it clear that whereas *Savannah* is essentially a 'pathfinding' project, the construction of a second US merchant ship would be dependent on economic considerations. In this connexion he stated: '. . . much has been said about economic nuclear propulsion for merchant ships. It has been argued that construction of nuclear merchant ships should be delayed for further research and development to permit competitive operation. The experience with the NS *Savannah* would appear to show that this point of view cannot be wholly justified since the initial effort of any country will require investment not only in "first of a kind" engineering and development for the ship itself but also a wide variety of maintenance, support and training programmes, facilities and equipment. These are major expenditures and amount to approximately 40% of the NS *Savannah* costs.'

A paper by Mr R. Shanstron of the General Dynamics Corporation referred to a design study of a high temperature reactor/gas turbine installation. The successful construction of such an installation may signify a brighter future for the marine gas turbine after the many setbacks and disappointments it has suffered.

Arising from a comparative study, France has decided to base its merchant ship propulsion development on the gas cooled graphite moderated reactor concept and, as a first step, is building a land-based reactor experiment. However, such an experiment can have wider uses and its construction does not necessarily imply that a nuclear ship will subsequently be built. Some other interesting French work is a study of the manouvering requirements of conventional ships; the object is to establish such criteria of manouverability as time from zero to maximum power and *vice versa* which are so essential to the designer of a reactor control system.

German work still appears to be concentrated mainly on the OMR concept. It is understood that preliminary arrangements are being made for Germany and Euratom to work in collaboration. In Italy, the design study begun some years ago by the Fiat-Asaldo combine has now reached a fairly advanced stage. Euratom support, particularly in the research and development field, is being sought.

Japan gave further information of a design study based on a small experimental ship of 4100 tons and having a 30 MW(t) reactor installation. No funds for this project have yet been granted by the Japanese Government. The Japanese have also undertaken studies on ship motion and on the design of collision barriers. Although a paper was prepared on collision protection it was unfortunately not presented to the Symposium so there was no general discussion on this vital subject.

Norway appears to have been concentrating on the influence of ship motion on boiling water reactors and as a means of confirming theoretical predictions has proposed that an experimental BWR be constructed inside a floating spherical containment vessel which can be rolled and pitched by means of four Voith Schneider propellers (Fig. 1).

The papers read by representatives of Messrs Yarrow and Co. Ltd, GEC, Rolls-Royce, and Hawker Siddeley reflected the continuing industrial in-

GENERAL IMPRESSIONS

1. The IAEA and IMCO have reached a good working arrangement for handling problems associated with international operation.

2. Many countries feel that further useful information and data can be derived only by the actual construction and operation of a nuclear ship.

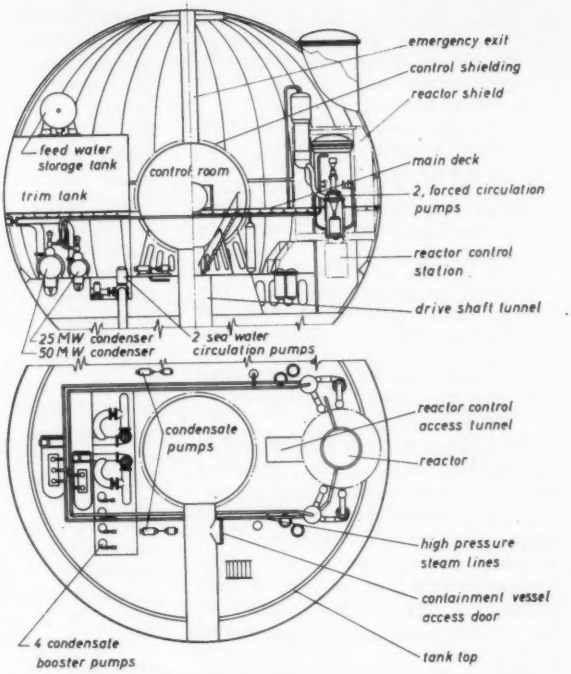
3. In no country, other than the USA and USSR, have design studies and economic assessments prompted governments or commercial interests to build a nuclear merchant ship. The USA has no plans at present for building a second nuclear ship.

4. Some countries are considering the possibilities of a joint European nuclear merchant ship project under the auspices of some such agency as the ENEA or Euratom. Although conflicting national and commercial interests could create some very difficult administrative problems, a joint European effort might well be the only means of providing European engineers and scientists with the fundamental construction and operating data needed.

wide range of reactor systems being considered in the UK.

The paper read by Mr L. W. Boxer of the European Nuclear Energy Agency appeared to be based on the report of the recent mission to member countries to ascertain the nature of European activity in the nuclear marine propulsion field. He said it appeared that in most ENEA countries, design study work had now been exploited to the full and further information could be obtained only from actual construction. It seemed, however, that most countries were diffident about embarking on a project involving such heavy financial investment, and research and development expenditure, when design studies indicated there might be no great economic return. For this reason, Mr Boxer suggested that a solution might lie in a European nuclear ship built under the auspices of the ENEA. He put forward two supporting arguments:

1. Capital and research and development costs would be shared.
2. Countries concerned would have an incentive to reach a common understanding on the legal, administrative, and operational problems associated with the international operation of nuclear ships in European ports.



Preliminary plant arrangement of the Rock 'n' Roll experimental facility (from paper NPS/19 by J. Wilhelmsen Jr., Norway) (Fig. 1)

Design rules

Papers were read by representatives of IMCO, Lloyds Register of Shipping and the Bureau Veritas on the statutory and classification society requirements for the design and construction of nuclear ships. Following these, Mr Krarup of Denmark presented a very good paper which compared the requirements of the various classification societies and those of the International Convention for the Safety of Life at Sea (SOLAS). He drew attention to apparent anomalies between certain of these requirements and also received some support from the floor in his justifiable criticism of the apparently arbitrary figures quoted in some cases. He added that whereas there were now quite a large number of regulations relating to the design and construction of the more conventional parts of reactor installation, the requirements for such important features as the fuel elements remained limited and vague. Mr Krarup agreed this was due to limited experience of fuel element behaviour but suggested that regulatory bodies should concentrate future efforts on requirements for such vital features in order to establish a more balanced set of rules. He concluded: 'It is evident that the rules formulated today will have to be subjected to continual and considerable alterations. This is being pointed out by the respective regulatory bodies. A development towards better agreement between differing rules must be anticipated as has been the case in the field of conventional ships. Great flexibility will be required from the respective authorities and societies to ensure that the development is not unnecessarily hampered or—which is even more important—side-tracked by decisions which creates precedents at early stages. The nuclear engineering of tomorrow must not be fettered by safety considerations which originate in today's lack of experience'.

Shields, fuels and waste disposal

Three interesting papers were read on the shielding of marine reactor installations. Those by Messrs A. Avery and J. Thunell indicated the important work physicists were doing in providing reactor designers with means of predicting the amount and arrangement of shielding necessary. Such information is very valuable as weight and space are important parameters. Mr J. C. Brown's paper dealt with the more practical aspects of shielding design; it attempted to establish the factors influencing shielding requirements and to evaluate the various materials at the designer's disposal, particularly from the point of view of economy in weight and cost.

Mr Bolander of the USA in his very good paper described the operations involved in refuelling *Savannah*. By showing slides and describing machines required for removing and replacing reactor head bolts and seal welds, he showed that refuelling a nuclear ship was not a minor operation.

In their paper, Mr Anscomb and his co-authors outlined the development of marine refuelling philosophy in the UK and drew attention to the influence of reactor design and refuelling cycles on the cost and duration of the refuelling operation. It concluded:

1. It is economically and mechanically practical to design a nuclear ship and the shore-based equipment so that refuelling can be safely and expeditiously undertaken in commercial ports.
2. Physical and mechanical considerations relating to reactor type and design influence markedly the choice of refuelling cycle.
3. Development of an acceptable scheme for the rail transport of irradiated fuel elements from the ship to the fuel processing plant, combined with suitable mobile units for dealing with radioactive wastes and contaminated materials, might eliminate the need for a nuclear servicing barge or equivalent port facility.
4. It appeared that:
   (*a*) There was some economic advantage to be gained by a continuous refuelling cycle but this might be largely, if not completely, off-set by the engineering problems and handling difficulties associated with operating refuelling machinery at sea.
   (*b*) Elimination of a nuclear servicing barge would markedly reduce the cost differential between continuous refuelling at sea and complete core replacement in port.
   (*c*) The effect of demurrage charges during refuelling periods in port

was marked and had to be taken into account when considering refuelling cycles which involve partial replacement and shuffling of the fuel at frequent intervals.

5. Further studies of the refuelling problem should be directed to:

(*a*) Establishing a scheme for the direct rail transport of irradiated fuel elements from the ship to the processing plant and investigating the provision of land mobile units for dealing with liquid waste disposal decontamination etc.

(*b*) Checking whether there was any real economic advantage from using cycles involving partial refuelling annually against the complete core replacement at longer intervals.

Mr Roberts, on behalf of the IAEA, surveyed the waste disposal problems associated with nuclear ship propulsion. He pointed out: 'The subject of radioactive waste disposal into the sea is continuing to receive very active interest by the International Atomic Energy Agency. The recent report of the *ad hoc* panel (sometimes known as the Brynielsson panel) of experts which studied radioactive waste disposal into the sea and the "Monaco Conference, on Disposal of Radioactive Waste" were expressions of this interest. In January 1961, a panel of legal experts will meet in Vienna to study the legal factors involved in implementing those recommendations which have an international character. Also a group of experts are invited to meet in Vienna in April 1961 to study means by which oceanographic radiation monitoring techniques can be standardized—an important prerequisite to the promulgation of standards and regulations. The International Atomic Energy Agency is also studying the factors and procedures required for harbour evaluation and hopes to be able to provide assistance in the form of experienced personnel to countries wishing to make harbour evaluations'.

An important contribution to the session on waste disposal came from Mr S. Morgan, Ministry of Agriculture and Fisheries, who gave a very lucid account of the factors and conditions influencing levels of activity and the nature of the isotopes which can safely be released into the sea. He also described methods used in the UK for establishing whether, and under what conditions, radioactive waste could safely be discharged into specified areas of water and quoted some typical examples from the UK studies.

Port assessment

The symposium was well timed in that it gave the countries represented a chance of discussing problems of port assessment before establishing their position *vis-à-vis* the forthcoming international operation of *Savannah*.

Five papers were presented, two by the USA, two by Norway, and one by Mr D. G. Bell of the UK. Captain C. D. Murphy of the US described the considerations which led to the SOLAS Convention requirements for port control and safety assessments of nuclear ships. Captain K. J. N. Wie, representing IMCO, said a nuclear ship safety committee had been officially appointed in Norway and one of its main tasks was to evaluate and classify the main Norwegian ports. He stressed the problem of assessment by enumerating some 25 factors, all of which have a varying influence on the suitability of a port for nuclear ships. The very nature of these factors emphasized the difficulty of basing an assessment on a fixed set of criteria and the need for a high degree of judgment by a team, each member of which is an expert in his own field.

The papers by Mr W. B. Cottrell of USA and Mr G. D. Bell were similar in that they both tried to define the criteria necessary to ensure that the population would not be endangered by a nuclear ship, either during normal operation or under accident conditions. The papers do, however, differ in emphasis; the UK paper treated an air release of radioactivity as being potentially the most dangerous, whereas the US paper appeared to treat a water release as of equal significance.

THE PAPERS PRESENTED

Economics and National Activities

NPS/23 J. Zamparo, Italy, Economic Analysis of Nuclear Shipping

NPS/8 E. Norton, UK, Marine Nuclear Propulsion Economics

NPS/21 Tomo Bosanac *et al.*, Yugoslavia, Some Aspects of the Propulsion Economics

NPS/37 L. W. Boxer, OEEC, ENEA Survey of Nuclear Ship Propulsion Activities in Western Europe

NPS/16 M. Yamagata, Japan, A Survey of Japanese Activities

International Problems and General Safety Aspects

NPS/27 H. N. E. Whiteside, IMCO, The International Conference on Safety of Life at Sea, 1960, New Regulations and Recommendations applicable to Nuclear-Powered Merchant Ships

NPS/35 A. Raspi, IMCO, Some Legal Problems Raised by the Operation of Nuclear Propelled Ships

NPS/31 W. C. Ford and R. P. Godwin, USA, NS *Savannah* Testing Experience

NPS/24 J. M. Pawlikiewicz, Poland, Some Safety Considerations of Ship Nuclear Propulsion Plants

NPS/33 C. K. Beck, USA, Safety of Nuclear Ships

NPS/6 H. Hildrew and J. McCallum, UK, Classification Standards

NPS/26 G. Bourceau *et al.*, France, Prospects of Framing Regulations Governing Classification of Nuclear Propelled Ships

NPS/40 Capt. C. P. Murphy, USA, Port Entry Control and Safety Assessment Provisions of the 1960 SOLAS Convention as applied to NS *Savannah*

NPS/38 N. Krarup, Denmark, Evaluation of Rules and Regulations for Nuclear Ships

Nuclear Ship Projects from the Safety Angle

NPS/22 L. Ghinaglia, Italy, Some Safety Problems in the Fiat-Ansaldo Nuclear Ship

NPS/5 S. G. Bauer and M. H. Kendon, UK, Method of Safety Analysis of a Steam Cooled Marine Reactor

NPS/7 T. J. O'Neill and M. C. Hartnell-Beavis, UK, Safety Aspects of the Marine AGR

NPS/41 W. C. Moore, USA, Safety Considerations affecting the design of the Maritime GCR

NPS/9 W. Smith and E. A. Ryder, UK, Control and Instrumentation of OMR plant in a Nuclear Ship

NPS/18 O. Knecht and H. Hausbeck, Germany, Investigations on the Safety of an OMR Ship Reactor

NPS/17 H. J. Bruchner, Germany, The effect of Direct Cycle Operation of a Marine BWR on the Safety of the Ship and the Crew

NPS/19 J. Wilhelmsen, Norway, Behaviour and Testing of Marine BWR's

NPS/14 M. Yamaguichi *et al.*, Japan, The Further Studies on the Small Experimental Nuclear Ship

Ship Reactor Problems

NPS/3 J. Brown and A. Jackson, UK, Shielding of Marine Reactors

NPS/4 A. Avery, UK, Theoretical Prediction of Neutron Penetration in Marine Reactor Shields

NPS/29 S. J. Thunell, Sweden, Neutron Fluxes in a Metal Water Shield —A Comparative Study

NPS/15 K. Kono and N. Omori, Japan, Study of Vapor Suppression for the Container of the Nuclear Powered Ship

NPS/28 I. R. M. Muysken, Netherlands, Effects of Scram on Maneuverability

NPS/25 L. Peffau *et al.*, France, Research on Optimum Maneuverability

Sea Motion and Hull Problems

NPS/13 I. Uchida and H. Yamaguichi, Japan, External Forces Acting on a Marine Reactor due to Sea Motion

NPS/39 D. Ulken, Germany, Testing of Structural Parts of Ship Reactors under simulated Service Conditions on board ship

NPS/20 M. Winsnes, Norway, Waves and Ship Motion during a Storm

NPS/11 K. Kagami *et al.*, Japan, Research on the Collision Resisting Construction of Ship Sides

Maintenance and Refuelling Problems

NPS/30 R. O. Mehann and D. F. Bolender, USA, Maintenance Planning for N.S. *Savannah*

NPS/2 R. Anscomb, R. O'Neil and J. A. Dodd, UK, The Refuelling of Nuclear Propelled Ships

Safety Aspects of Nuclear Ship Operation

NPS/36 R. Barker and C. Roberts, IAEA, Survey of Waste Disposal Problems in Nuclear Ship Propulsion

NPS/34 W. B. Cottrell, USA, Accidental Activity Release

NPS/42 Capt. W. J. N. Wie, IMCO, Evaluation and classification of ports

NPS/1 G. D. Bell, UK, Safety Considerations arising from the Operation of Nuclear Ships in Port

NPS/32 J. Thomas and O. Kofoed-Hansen, Denmark, Shore Safety

Our concluding article, on reactivity coefficients and flux distributions, emphasizes the inherent safety and flexibility of this reactor

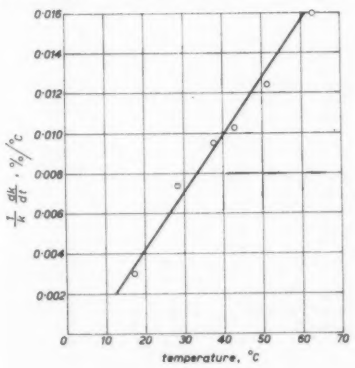
Jason operating experience—2

by J. C. BOLTON, B.A., Deputy Reactor Supervisor, and M. G. TENNET, B.Sc., Hawker Siddeley Nuclear Power Co. Ltd

WITH A VERY large reactivity addition to Jason, large voids would be introduced through boiling and the system would rapidly become subcritical As it is desirable to be able to predict the quantitative behaviour of the system when there is any increase in reactivity, the void and temperature coefficients have been measured.

Temperature coefficient

The temperature coefficient was measured over the range 18°C to 65°C and was found to be linear over that range, within the limits of accuracy of the measurements (Fig. 6). Since the upper temperatures at which the measurements were made were much higher than the operating temperature at full power, the cooling water had to be heated by means of three 7 kW immersion heaters located in the dump tank. The water was heated up to 70°C, the heaters switched off, and the system allowed to cool down. Measurements of the reactivity of the system were made at intervals of a few degrees. At the highest temperature, the system was just subcritical; the reactivity was measured by noting the subcritical flux level and relating it to the flux level at a known subcriticality. At lower temperatures, the positive reactivity was obtained either by positive period measurements or by making a critical setting. The three methods used for reactivity measurement all gave consistent results, and the resulting graph of $(1/k)(dk/dt)$ against temperature is shown in Fig. 6.



The temperature coefficient of reactivity is linear over the temperature range 18°–65°C (Fig. 6)

REACTIVITY COEFFICIENTS

The Jason reactor owes its inherent safety and stability to its relatively large negative void and temperature coefficients of reactivity. The reactor is slightly undermoderated and any reduction in water density, either by thermal expansion or by introduction of voids, will reduce the reactivity of the system. Any increase in reactivity will cause the power and temperature of the system to rise which in turn will decrease the reactivity of the core.

Void coefficient

The void coefficient throughout the core was measured by inserting hollow perspex plates in between fuel plates. The voids in the perspex plates were about 40 cc per plate and could be filled with water. Critical settings were taken both with the space filled with water and the space in the plates empty. The difference between these two settings gave the amount of reactivity absorbed by a void of known volume and hence the void coefficient. This was found to vary from about $-0{\cdot}53\%\ k/\%$ void at the centre to $-0{\cdot}27\%\ k/\%$ void at the outside of the core.

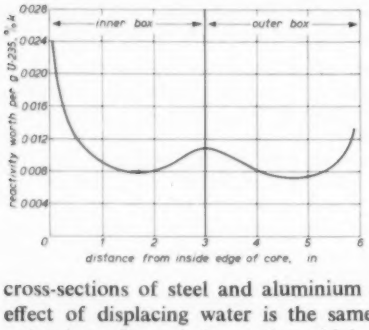
Poison and fuel worth measurements

In order to predict the effect of changes to the core, it is of interest to determine the reactivity effect of removing fuel plates and also the effect of inserting some neutron absorbers at various points throughout the core.

The reactivity worth of fuel plates was determined by removing individual plates from various parts of the core and obtaining critical settings. By comparison with the critical setting for a normally loaded core this gave the reactivity worth of particular plates and, hence, the fuel worth as a function of position. A typical fuel worth plot across the slab core is shown in Fig. 7. The core has the width of two fuel boxes and there is a larger gap than the normal plate spacing between the two boxes. With normal fuel spacing the core is under-moderated and the larger

water gap between the fuel elements results in a peaking of the fuel worth at that position.

The poison worth distribution was measured by inserting a long steel strip—a half inch wide, 0·080 in thick—in between fuel plates. This was inserted in a large number of positions throughout the core and critical settings were noted for each position. Comparison of the critical settings with a normally loaded core and with a steel strip inserted in a particular position gave the reactivity worth at that position. Part of the reactivity change will be due to the displacement of moderator by the steel and part due to the neutron absorption in steel. The former effect was allowed for by replacing the steel strip by an aluminium strip of the same dimensions. Since the absorption



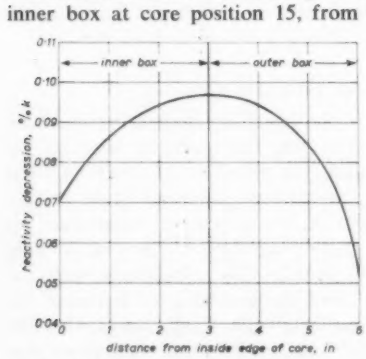
Typical fuel worth plot taken across the slab core (Fig. 7)

cross-sections of steel and aluminium are known, and the effect of displacing water is the same in both cases, the poisoning effect of the steel could be calculated. A typical poison worth curve across the slab core is shown in Fig. 8.

Flux distribution

In April 1960, the neutron flux was measured at over 400 different positions in the core of Jason. The flux distribution is complex and such wide scale measurements were necessary to enable a reliable estimate of the thermal power output to be made; since this is limited to 10 kW, and the heat losses are large, it is impossible to do so thermodynamically.

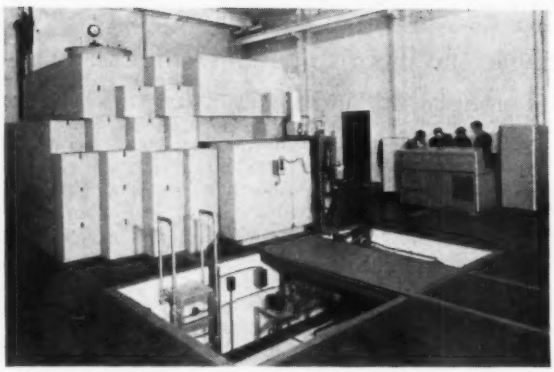
Descriptions of Jason appeared in *Nuclear Power*, March 1959 and Dec. 1960 (see Fig. 9 for an overall view of the reactor). The fuel loading at present is a single slab, both inner and outer boxes (see Fig. 10) being present in core positions 11 to 15 and the outer box only at core position 10, the inner position is filled with a graphite block. All boxes contain their full loading of 16 plates but for the inner box at core position 15, from which plates 1, 2, 5



Poison worth plot taken across the slab core (Fig. 8)

and 10 are missing (the plate positions are numbered sequentially outwards from the inner thermal column).

The flux measurements in the core region were only relative, manganese foils, 0·25 inches dia. and 0·005 inches



This overall view of reactor shows the position of the dump trench (Fig. 9)

thick, were used for this purpose, while one absolute determination of flux was made in the central hole of the inner thermal column using gold foils 0·25 inches dia. and about 0·001 inches thick. The gold foils were irradiated bare and under cadmium at a power of about 14 W for one hour, and their activity was determined by β-γ coincidence counting; the manganese foils were irradiated bare only (the necessary cadmium ratios had been determined previously, the spectrum correction between positions is extremely small) for 30 min. at 0·5 W and then β-counted. Double geigers were used for this purpose; the foils were placed 20 at a time on a tray which circulated past 4 double geiger assemblies; each foil was counted until a pre-determined number of counts had been recorded for a fixed timer foil, thus automatically making the necessary decay corrections, while dead time corrections were made by an electronic sampling device. On average about 100,000 counts were recorded for each foil having good statistical accuracy.

Two types of holder were used to locate the manganese foils within the core, both made of $\frac{1}{16}$ in sheet celluloid. For measuring the axial and azimuthal variations of flux, the holder was 2·2 in wide and 30·5 in long with 0·015 in deep depressions milled to receive the foils at suitable

Brief specification of the Jason reactor

		10 kW	100 kW
Type		Thermal, heterogeneous with annular core	
Coolant		H_2O	
Moderator		H_2O	
Reflector		Graphite, internal and external	
Maximum continuous power, kW		10	100 (for 40 h)
Average continuous power, kW		10	10
Maximum thermal neutron flux, n/cm² s		$1·5 \times 10^{11}$	$1·5 \times 10^{12}$
Approx. critical mass		Annulus 4·2 kg; one slab 2·0 kg; two slab 3·8 kg	
Fuel		MTR type, about 90% enrichment	
Experimental facilities			
1. Thermal column	(*a*) no. of holes	12—4 in × 4 in 1—4 in × 12 in	
	(*b*) approx. flux at inner surface, n/cm² s	3×10^{10}	3×10^{11}
2. Beam holes		2—3 in sq.	5—3 in sq. passing through reactor
3. Shield tank	(*a*) dimensions	86 in × 48 in × 42 in	—
	(*b*) approx. flux at inner surface, n/cm² s	10^{10}	—
4. Mobile thermal column	(*a*) no. of holes	—	12—4 in × 4 in 1—4 in × 12 in
	(*b*) approx. flux at inner surface, n/cm² s	—	3×10^{11}
5. Internal thermal column		24 in diameter 5 vertical stringers	

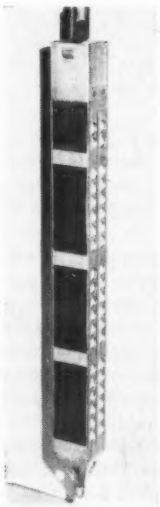
intervals ($\frac{1}{2}$ in separation in the regions of most rapid flux change, 1 in or 2 in separation elsewhere). Small celluloid blocks glued to the faces of the holder located it vertically by resting on top of the fuel plates; the horizontal location was ensured by the edges of the holder butting against the sides of the fuel box top. The second type of holder, for measuring the radial flux distribution, was 26·1 in long and 0·5 in wide; depressions at fuel mid-height and at 9 in above and below mid-height received the manganese foils. It was supported between the plates as described above.

The flux measurements were spread over six days. To enable the results to be interrelated, a monitor foil was irradiated at a fixed position and subsequently counted along with the other foils (the foils used for this purpose were later inter-calibrated to allow correction for their differing manganese content).

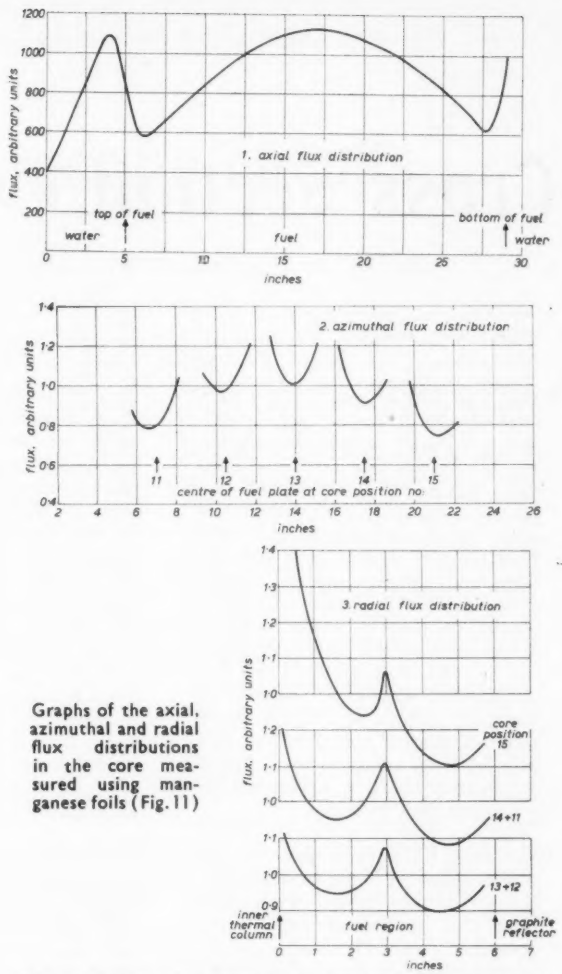
Graphs 1, 2 and 3 of Fig. 11 give the axial, azimuthal and radial flux distributions obtained from these measurements. The axial flux distribution was found to be almost identical in the six core positions, the form factors varying by only 1% about the mean. The flux peaking in the water reflector above the core is well illustrated, the flux being only fractionally less than at core mid-height. It will be seen that the control plates have caused a slight asymmetry, depressing the flux at the top of the core relative to that at the bottom.

Graph 2 shows the azimuthal flux distribution at a position about $2\frac{1}{4}$ in out from the inner thermal column. The circumferential separation of the fuel plates is about 0·9 in, 0·6 in of the gap is filled with graphite, the remainder with aluminium and water. There is a considerable local flux depression across the fuel plates, about 20% difference between the edges and the centre. The flux on the shield tank side of the core is somewhat higher than that on the thermal column side, although this is somewhat obscured by the graphite block at the inner box position of core position 10.

The most complex distribution is that in the radial direction. There is a general fall in flux on moving outwards, but superimposed on this are local depressions at the centre of the fuel boxes and a peaking in-between the boxes where there is a larger water gap than normally



A Jason fuel box, which contains 16 fuel plates, is 3 inches square with an active length of 2 ft (Fig. 10)



Graphs of the axial, azimuthal and radial flux distributions in the core measured using manganese foils (Fig. 11)

exists between fuel plates. The flux variation across the annulus is greatest in core position 15, in part due to the fuel plates missing from the inner box, and least in the centre position 12 and 13.

The graphs give a good idea of the flux distribution through the core of Jason and have enabled the power output to be related satisfactorily to the flux at a particular position (opposite the centre of the core and 1 in into the central thermal column, a flux of $1{\cdot}8 \times 10^{11}$ n/cm^{2}s at 10 kW). However, further measurements will be made.

In particular, it is intended to use a different type of foil holder, made of perspex and inserted into the box from the side rather than from the top, to give much better foil location for the radial and azimuthal flux measurements; it will also be used to make measurements at different points across the water gap between fuel plates (to find the 'ripple structure'). For these measurements a box containing fuel plates of low activity will be used, replacing the 'hot box' normally in the core at the position of interest; this will enable the measurements to be made without any health hazard arising when the foil holders are positioned.

Acknowledgment

Thanks are due to Mr P. Bomyer and Mr D. Wallace of AWRE, Aldermaston, for determining the gold-foil activity, and for the loan of the β-counting equipment.

Cross Section by GRACCHUS

WITH THE RAPID growth of the AEA establishment at Winfrith Heath, Harwell is in danger of losing the glamorous role it has held for years. Winfrith, with its new buildings and nine reactor assemblies, will be the place to watch for future developments. Apart from the two reactors from Harwell, Nero and Dimple, and the further assemblies for the study of reactor physics, the main work will be keyed to the improvement of magnox reactors and the development of the high temperature gas-cooled reactor. It would not surprise me to see a future marine land-based prototype developed here; after all, a team from the British Shipbuilding Research Association has a foothold there already.

TWO PUBLIC opinion polls in the United States on public attitudes concerning atomic energy surprisingly show that in general, the average American is relatively uninformed and confused about its peaceful uses. They conclude that much of the public information on atomic energy to date has been over the heads of most people; the less a person knows about nuclear energy, the more he tends to doubt its value. He would even tend to reject it as menacing, undesirable and only constituting an additional hazard. The surveys make interesting reading and I recommend them—particularly to those in the AEA who think the Authority's travelling exhibition 'Atoms at Work' should be scrapped. I am surprised that serious consideration should have been given to such an idea. I should have thought the attendance figures alone would have proved the worth of the exhibition. After all, if the AEA is not to 'educate' the public in this way, who is?

There are enough misconceptions already about atomic energy without useful work in this direction being curtailed. Indeed, there is a strong case for increasing the amount that should be done—perhaps by enhanced co-operation between the AEA and industry in this field and more open days at AEA establishments. No one wants a negative public attitude; certainly, one should work to dispelling the type of reply 'I am fearful of it (atomic energy) because I don't understand it' that was quoted in one of the surveys. And in this respect, it was interesting to hear Sir Roger Makins' views at the 'Atom in Camera' photographic exhibition at Ilford House. At the opening ceremony, he stated: 'There is bound to be a certain amount of fear and apprehension, and not a little prejudice, about so revolutionary and potent a discovery as energy from the atomic nucleus. It is my belief that these feelings and emotions are diminishing in strength and intensity in the UK . . .'.

IT'S INTERESTING to hear that radioactive caffeine is now available commercially in the United States. This new compound is known chemically as 1-methyl-C 14, -3, 7-dimethylxanthine—quite a mouthful whichever way you look at it. Apparently doctors and biochemists will use it for research in determining the effect caffeine has on the heart, respiratory and nervous systems. Anyone for 'hot' coffee?

NUCLEAR PROPULSION is very much the vogue in the United States. I hear that passages on the US nuclear ship *Savannah* are so popular that when she does eventually take passengers, the berths will be fully booked for a long time ahead. Requests for the 60 luxurious passenger places are so numerous that bookings are virtually complete for the next few years.

UNIVERSITY reactors seem to be very much in the news these days. Questions in the House of Commons have been asked, and licences and details of the reactors to be built have been issued. All it needs to make the picture complete is for someone, somewhere, to start building one. I just wonder why all this has taken so long. Could it be a case of shilly-shallying? The delay seems to be somewhere in somnolent Whitehall. One of the reasons, apart from not considering applications individually but trying to get as many together as possible, is apparently confused thinking in the Treasury, which is mixing up source reactors with larger reactors and asking Universities whether they would not, in fact, like a 1 MW reactor. The delay in issuing funds may well make other universities think it will be quicker to go through the Grants Committee.

THE CEGB is soon to announce whether or not it intends to go ahead with the proposal to build a nuclear power station near Newtown, in the Isle of Wight. Formal application has not yet been made but I understand that opposition is likely to come from the Isle of Wight Society, the Solent Protection Society and the Council for the Preservation of Rural England.

A NEW association, this time of individual firms in the nuclear industry, may make its appearance within the next twelve months. That august body, the Federation of British Industries, is, I understand, discussing ways and means of bringing this about. Their interest follows a recent meeting of the FBI's Grand Council when a paper putting forward the idea of the association was approved without dissent. This may, of course, bring the FBI into conflict with the aims of NETAC (Nuclear Energy Trade Association's Conference). This body—an association of associations—was, I recall, set up in 1956 to provide a permanent means of liaison between different sections of the British engineering industry on matters relating to nuclear energy and related developments.

On Record

'The things we don't know; the things we don't even know we don't know; the things we "know" that aren't so—these constitute our veritable infinity of ignorance—the basis of a useful, exciting and rewarding lifetime of research.'

Dr Norman Hilberry, Director of Argonne National Laboratory, speaking on a career in research at the 2nd National Youth Conference on the Atom, Chicago.

'If the British (advanced) gas-cooled reactor were successful . . . and were duplicated in say a dozen places in the world, then the beryllium requirements for this purpose alone would far exceed all of the beryllium metal produced today for all purposes taken together.'

Bruce Odlum, president, Beryllium Resources Inc., at the Utah Securities Dealers Association, Salt Lake City.

' Use of alloy steels would ease fabrication and inspection procedures as well as cutting costs '—Sir Leonard Owen

Steels for reactor pressure circuits

A BNEC Symposium reported by
G. E. DARWIN, M.A., A.Inst.P., A.I.M., Babcock & Wilcox Ltd

THE FIRST SESSION covered high temperature properties of low alloy and carbon steels such as have been chosen for all reactors now under construction. Robertson and Nichols gave a summary of the wealth of creep and stress rupture results which are now available. While the creep results are undoubtedly of great value in assessing the amount of deformation to be expected in a vessel, little use can be made of the rupture figures as significant and intolerable distortion must arise before rupture can occur. The designer can eliminate creep and rupture difficulties either by internal insulation and external cooling of the vessels or by the use of alloy steels. The paper by Glen and Murray concluded that creep in carbon steel is mainly influenced by the active nitrogen content. Thermal treatments or alloy additions can cause precipitation of nitrides resulting in a lowering of the creep strength. In the discussion no serious attempt was made to refute the strong case put forward for this theory.

The programme included a third paper for that session on graphitization but the late arrival of four other papers reduced the overall time for discussion to a minimum. Two of these four covered graphitization and two, creep and stress relaxation. From these arose one of the most striking results of the whole Symposium. The paper by Wood and Swift made absolutely clear the penalty in creep strength resulting from stress relieving. Not only can the creep properties be seriously affected but the transition temperature can rise considerably as was shown by the paper, given the next day, by Holliday and Noone. Boyd suggested that pursuing stress relief to the ultimate was a mistaken policy and the paper by Wood now shows what times and temperatures are needed for any selected residual stress. Wells pointed out that the removal of more and more stress became progressively less worthwhile from the brittle fracture viewpoint. A figure of 50% of the yield strength for carbon steel might be satisfactory but one must remember that vessels are stress relieved partly in order to redistribute triaxial stresses which would otherwise be additive to the operating stress and affect ductile performance. As relaxation of stress and loss of properties do not necessarily occur in the same proportions for every temperature and time, and re-investigation might be worthwhile to establish what times and temperatures are necessary to give the optimum stress relaxation and minimum loss of properties. The three papers on graphitization did not arouse great interest, but are nevertheless valuable additions to the sum of our knowledge on this potentially important phenomenon.

About 500 scientists and engineers attended the three-day symposium organized for the British Nuclear Energy Conference by the Iron and Steel Institute in late November 1960. Among them were a notable number of overseas visitors including large contingents from most European countries and the United States.

Corrosion

The afternoon session on corrosion was probably the most lively of the Symposium as a result of the determination of the Chairman (Dr Finniston) and of the adequacy of the time for question and answer. The paper by Raine and Moore discussed CO_2 oxidation using results obtained by all the consortia and the UKAEA. The principal problem is that, in CO_2, oxidation only follows a parabolic law for a limited period and then breaks away. The paper was notable for its microphotographs of the excrescences which can form particularly on the rimming steels sometimes used in heat exchanger extended surfaces. Two theories for breakaway were put forward. The one favoured by the authors postulated simultaneous oxidation and carburization which Hoar pointed out was perfectly feasible with certain CO_2/CO ratios. In general, however, there was more support for the theory due to Robinson who ascribed the more rapid oxidation to the acceleration of oxygen diffusion by impurity induced defects in the oxide film. Stevens reported a neat experiment in which breakaway oxidation was started and stopped by adding and removing moisture from the gas. Ball reported some results on uranium oxidation which could be used as evidence to support Robinson's theory. Clearly, however, neither theory explained all the results and an unsatisfactory situation exists. No real worry is to be expected in the current civil reactors but as gas temperatures increase, a massive release of oxide particles into the gas circuit could increase operational difficulties. The second paper in this session by LaQue and Cordovi summarized the corrosion of steels and nickel alloys in water cooled reactors. The third paper by Tyzack reviewed the current position on corrosion and mass transfer in sodium.

Fabrication

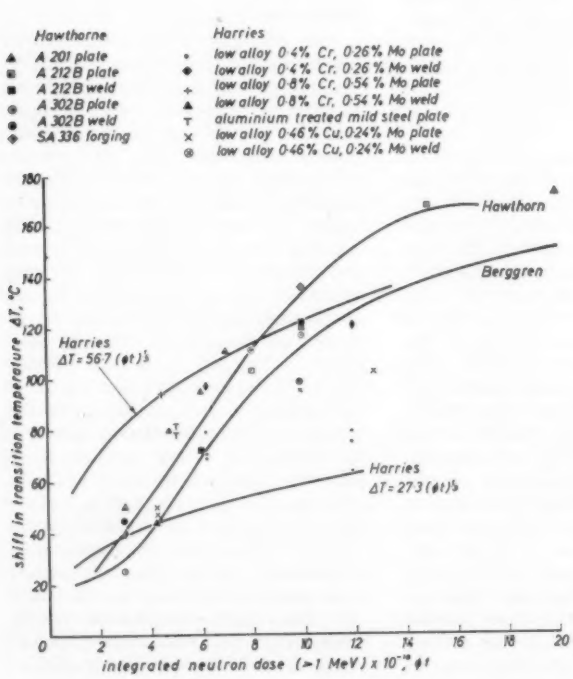
The first paper by Holliday and Noone of the session, the next morning, described in great detail the fabrication methods used by their firm for gas cooled reactor pressure vessels, together with the various experiments carried out to establish procedures. One of the experimental results showed that proper control in pressing of plate obviated the need for subsequent normalizing. The suggestion in the discussion for the use of properly controlled local stress relieving of welds and adjoining plate seems admirable, but the Safety Authorities are likely to take a lot of convincing on the adequacy of this procedure. The second paper described the fabrication of the pressure vessel and other components for the Dounreay reactor. This worked very little discussion apart from mention of the various radiographic techniques used. It certainly seems that cost was a secondary consideration in the design of 'The most complicated reactor vessel' ever built. An extra paper by Bartocci and Marianeschi described

the procedures being used for the fabrication of the SENN boiling water reactor vessel. A film illustrated the forging procedures used to produce the complete rings. This process reduced the amount of welding, but the authors admitted that it was more expensive by 10%.

Irradiation effects

The remainder of the day was devoted to irradiation effects and no less than eight papers were presented. In the first, Cottrell produced an extension to his now well-known theory relating the rise in transition temperature to the cube root of the irradiation dose. Immediately afterwards he had to withstand a vigorous onslaught by Allen but, apart from minor and admitted breaches in his defences, the attack was beaten off. Then followed the paper by Harries, Judge and Nichols reviewing UK information on the effect of irradiation on the ductile to brittle transformation temperature. The three American papers by Steele, Hawthorne and Berggren summarized their results, an interesting film on dosimetry being shown by Steele. Trudeau brought up to date his results on the effect of composition on irradiation embrittlement. Rossin produced a theoretical paper discussing the effectiveness of neutrons of different energies. Lowe and Weissert described the effect of high temperature (up to 925°C) irradiation on a low alloy steel.

In view of the large number of results now available, some comparison would seem worthwhile. The results of Hawthorne for irradiation below 200°C are shown in Fig. 1. The results of Harries for 130°C all lay within the zone defined by the equation $\triangle T = K(\phi t)^{\frac{1}{3}}$ where K lay between 27 and 56·7, the Cottrell figure being 55. The plot of these lines is also shown in Fig. 1, although perhaps some flux correction should be made as their doses were, strictly speaking, sulphur rather than 1 MeV. Figure 1 also shows Berggren's preferred line. Trudeau's results show significant differences between different steels and he concluded that steels of increased purity had a smaller rise in transition temperature, while the presence of free carbide accentuated the rise. Irradiation temperature has a marked effect on embrittlement, Berggren suggesting that in A.212B steel the damage resulting from a given dose decreases above 220°C. The results of Harries on Ducol W.30 show an increase in damage on increasing the irradiation temperature from 80 to 130°C, a considerable decrease at 290°C and negligible damage at 325°C. The results of Hawthorne and Weissert both show reduced damage at higher temperature, although, in the latter case, some damage was still found above the Ac_1 temperature of 780°C. Hawthorne also investigated the effect of post-irradiation annealing and showed that considerable recovery is possible. The percentage reduction of irradiation induced rise in transition temperature was less for higher irradiation temperatures, but, even so, annealing of irradiated reactor vessels might be highly desirable should the damage become excessive. As was pointed out in discussion, the main need now is for a better understanding of irradiation damage. Several types of work are required now including an extension of Trudeau's programme on the effect of composition and something on the lines of Rossin's theoretical study of the effect of neutron energy. Should better calculations of the neutron spectrum in actual reactors become available, more accurate predictions of damage could be made.



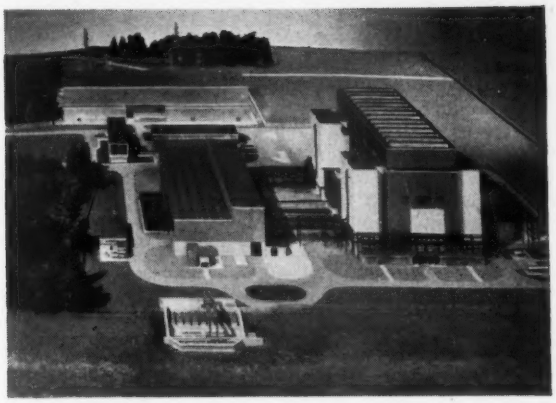
The effect of irradiation below 200°C on the ductile to brittle transition temperature in carbon and low alloy steels (Fig. 1)

Steels for future reactors

The Friday morning session concerned low alloy steels and included papers from the four principal Steel Companies concerned. A wealth of information was presented and there seems to be no objection from the steelmaking viewpoint to the use of alloy steels in heat exchanger shells and reactor pressure vessels. The authors suggested keeping the carbon content low, which would ease welding, an aspect not discussed in detail as it was considered inappropriate to the Symposium. The afternoon was devoted largely to contributions stored up from previous days, an arrangement which was only partially successful due to poor attendance. The now familiar arguments on the different brittle fracture tests were elaborated. Benson thought that the time had now arrived for tests on actual vessels and a good case can certainly be made for this type of work rather than for a continuation of the current type of work which is becoming progressively more expensive. Such tests should incorporate realistic defects and stressing below the transition temperature would allow a full appreciation of the real results of irradiation damage.

The Conference as a whole must be judged a considerable success in view of the enormous amount of data released. It is unfortunate that the time available in some of the sessions did not allow complete discussion of the results. The irradiation damage picture is now becoming much clearer and it would now seem timely for more basic and theoretical work to be carried out so that adequate correlations can be obtained. Spectrum determinations in the civil reactors and tests on actual vessels below the transition temperature would allow the irradiation data to be applied in a positive manner to the actual conditions under which a vessel will operate. The high temperature CO_2 oxidation picture is not so promising and further basic work is needed to elucidate the mechanism of breakaway.

English Electric's design for Sizewell



The CEGB's sixth nuclear power station will supply 580 MW to the supergrid

AN EMPHASIS ON compactness is the main characteristic of Britain's latest nuclear power station. As expected the contract has gone to the English Electric, Babcock and Wilcox, Taylor Woodrow Atomic Power Group (see *Worldview*). Work on site will start in April 1961 and the first reactor should be in operation in 1965, with full output capacity of 580 MW expected in 1966. This will supply base load for the rapidly growing electricity demand, particularly high in the south-east of the UK. This is the Group's second contract and comes at a time when the 500 MW Hinkley Point station is nearing completion.

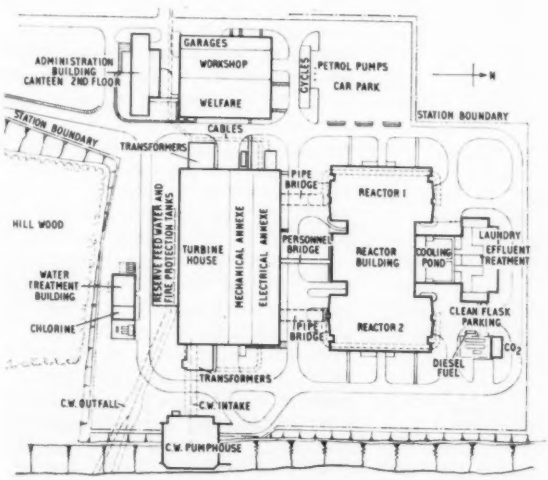
The contract price of £55,000,000 is the same as for Dungeness though the sent-out capacity is some 30 MW greater. On this basis the capital cost is £95/kWso though what the site development charges are and how they will affect the capital cost is not known.

The design follows the same general pattern of graphite moderated, carbon dioxide cooled, natural uranium fuelled type as previous CEGB stations but some features have led to a reduction in the physical size of the station and thus the capital cost. The most notable is the housing of both reactors under the same roof though this will require careful phasing of the civil engineering programme. It will give the most economic use of the pile cap services and allow a single central fuel discharge system, together with a single compact cooling pond. The refuelling and servicing machines can be transferred and operated on either reactor. The space between the two reactors is for the common control room, change rooms, plant rooms etc. Economy of space has been achieved in the turbine hall by having only two very large sets of 325 MW output each. It is reported that by going to sets of this size a saving of about £2/kW has been made.

Comparison of Sizewell and Dungeness parameters show some slight differences, apart from the method of blower drive, and these can presumably be explained in terms of the different methods of optimization employed. An interesting difference is the quoted efficiencies for the two stations; 30·5% for Sizewell and 32·9% for Dungeness. The heat ratings are slightly different, Dungeness 2·8 MW/t and Sizewell 2·95 MW/t; both are lower than that for Trawsfynydd 3·1 MW/t.

Sizewell is situated on the coast roughly midway between Ipswich and Lowestoft, the nearest large towns. The site is separated from the North sea by a low line of sandhills and is bounded by woods to the south and east. A new road will connect the site with Leiston. A photograph of a model of the site is shown at the top of the page. The top soil is mainly fine to medium sand with the water table 29 ft below the finished ground level. The substrata, also sand, has good load bearing characteristics.

The two main structures, the reactor building and turbine hall, are parallel to one another and at right angles to the sea. The general arrangement of these buildings to the other facilities is shown in the site plan (Fig. 1). The turbine hall has been sited to give a minimum length of circulating water culverts from the pumphouse which is connected to an intake structure, some 1375 ft offshore, by twin tunnels.



Site plan showing the compact layout; final area will be 24 acres. During construction the area occupied will be 160 acres (Fig. 1)

The reactor building

Each of the two reactors will consist of a spherical pressure vessel 63 ft 6 in dia. housing a graphite core supported on an orthogonal lattice grid of Warren girders. A 5 ft 6 in thick concrete primary biological shield surrounds the reactors and forms the main structural members of the building. The reactors are sealed by an 11 ft 9 in thick roof extending over the area between the reactors. A supplementary shield, about 5 ft thick will be placed around the primary shield to mask the major shield openings for coolant gas and air ducts.

Fuel elements

An improved fuel element can has been evolved allowing higher heat ratings than in previous Group designs. The extended surfaces of the magnox can are to be of the polyzonal multi-start helical thread type allowing an increase in outlet gas temperature, though what this is has not been released by the Group. The Hinkley Point stacking technique is to be used and a mean irradiation level of 3000 MWd/tonne is expected. Conventional solid uranium rod is used and it has not been necessary to go to hollow fuel to obtain the outlet temperatures required.

Control

Reactor temperatures and heat output are to be kept steady by an automatic reactor control system. Major alteration in reactor heat output will be made by changes in coolant gas mass flow. This is to be done by varying the setting of the circulator inlet guide vanes and the operation of an elegant gas by-pass system. Reactor gas outlet temperature is to be controlled by a sector control-rod system and xenon reactivity override obtained by raising the inlet gas temperature.

Gas circulators

The coolant gas will be circulated by single stage axial blowers with variable stagger inlet guide vanes. These blowers, one to each boiler, are to be driven by large constant speed a.c. induction motors drawing power from the main station generators. This blower drive differs from that adopted for Dungeness which will use back pressure turbines driven by high pressure steam. This has advantages from the safety point of view. The Sizewell choice, however, has the merit of established reliability. Each blower, mounted vertically in the base of a boiler, can be readily withdrawn for maintenance.

Reactor pressure vessel

The spherical vessel will have walls over 4 in thick and an internal diameter of 63 ft 6 in. The vessel plates, pre-shaped and part welded at works, will be welded together at site into courses of a size to make full use of the Group's Goliath crane. This will shortly be transferred from Hinkley Point to Sizewell. The top of the reactor vessel will be protected from high temperature gas by internal insulation and metal temperature further reduced by the use of a cooling cowl on the outer surface. The core load is to be transmitted through the vessel envelope by an annular cruciform section forging. There will be about 300 nozzles and penetrations, ranging in size from the 6 ft 6 in i.d. gas inlet and outlet openings to small sampling and test closures, in each vessel.

Boilers

There are to be four boilers per reactor, in pairs on opposite sides of the reactor building, with shells fabricated from low alloy, high tensile steel. This steel gives appreciable savings in metal weight and thickness and simplifies site fabrication and erection problems. Shell sections will be prefabricated at works and sent by sea direct from the manufacturer's wharf to Lowestoft.

Boiler elements are planned in horizontal banks. The heat exchange surface design has advanced so far that each boiler will produce over 50% more steam from a shell little bigger than those at Hinkley Point. As in the earlier stations, a dual pressure steam cycle will again be adopted but with a side-by-side superheater arrangement to give a maximum L.P. steam superheat. The number of shell penetrations is to be reduced by the use of trifurcations connecting groups of three elements into a single tube passing through a thermal sleeve in the boiler shell.

An interesting feature of the design is the inclusion of a by-pass within the boiler shell to control the exit temperature of the gas from the bottom of the unit. The difficulties of controlling gas flow to the by-pass have been overcome by having the valve system actuated from outside the boiler shell through a displaced bellows positive seal drive.

The bottom end of the boiler shell will provide space for the circulator, control valve and by-pass system, the whole unit being so arranged that it can be withdrawn from the bottom of the boiler for maintenance. Further developments in boiler control should make it possible for all the boilers to be operated while on load from a shielded room in the boiler house basement, thus eliminating the need for personnel to enter radiation areas during operation.

Electrical engineering

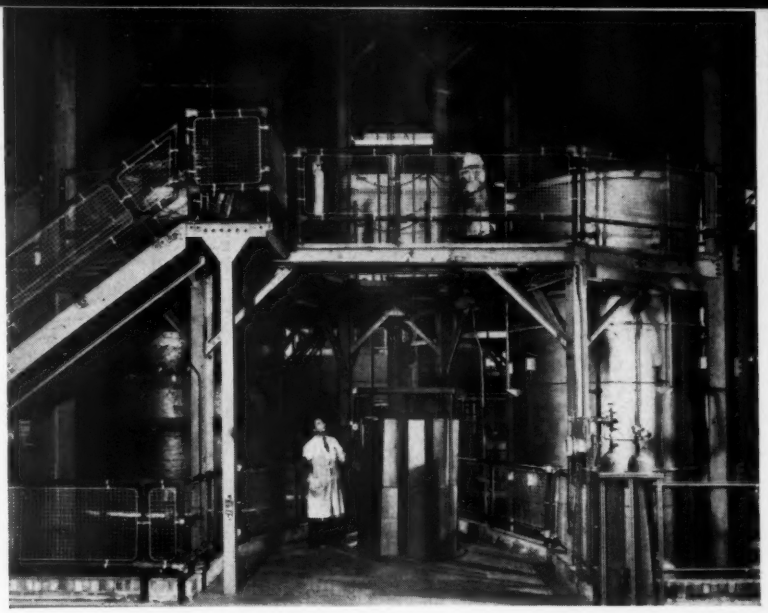
Each turbine is to be a 3000 rev/min in line tandem compound machine with one H.P. cylinder and multi double flow L.P. cylinders, the latter employing the longest exhaust blades yet manufactured. The turbines are to be mixed pressure machines and one of the novel features will be the use of bled steam to reduce exhaust wetness. The high pressure cylinder will use steam at 646 lb/in²g and 700°F, the low pressure cylinder taking steam at 253 lb/in²g and 700°F.

The 3-phase 50-cycle alternators, each rated at 382 MVA at a power factor of 0·85 lagging, will generate at 17·5 kV. Direct cooling will be employed, using water in the hollow stator conductors and hydrogen at a pressure of 45 lb/in²g in the hollow rotor conductors, the hydrogen being circulated by a blower mounted directly on the main alternator shaft.

PRINCIPAL DATA

STATION	
Nett electrical output	580 MW
Nett thermal efficiency	30·5%
REACTORS	
Number of reactors/station	2
Reactor heat rating	950 MW
Pressure vessel diameter	63 ft 6 in
Pressure vessel thickness	over 4 in
Coolant	CO_2
Reactor inlet pressure	279 lb/in²a
Fuel	Natural uranium
Fuel rod diameter	1·1 in
Fuel charge/reactor	321 tonnes
Mean fuel heat rating	2·95 MW(th)/t
Number of elements/channel	7
BOILERS AND TURBINES	
Number of boilers	8
H.P. drum pressure	720 lb/in²a
H.P. superheater outlet temp	391°C
L.P. drum pressure	305 lb/in²a
L.P. superheater outlet temp.	390°C
Steam press. at H.P. boiler stop valve	677 lb/in²g
Steam temp. at H.P. boiler stop valve	389°C
Steam press. at L.P. boiler stop valve	268 lb/in²g
Steam temp. at L.P. boiler stop valve	389°C
Vacuum	29 inHg
H.P. steam flow from each boiler	$5{\cdot}4\times10^5$ lb/h
L.P. steam flow from each boiler	$1{\cdot}9\times10^5$ lb/h
Boiler dimensions	91 ft 6 in × 22 ft 6 in
Number of main turbines	2
Output of each turbine	324·75 MW
MAIN CIRCULATORS	
Number of circulators	8
Type of circulators	Vertical, single stage axial with variable stagger inlet guide vanes
Drive	Vertical squirrel cage induction type motor
CIVIL ENGINEERING DATA	
Height of reactor building	193 ft
Length of reactor building	400 ft approx.
Mean thickness of concrete main shield	5 ft 6 in
Mean thickness of concrete supplementary shield	5 ft
Distance across flats of main shield	72 ft 3 in
Height of concrete main shield	86 ft 2 in
Thickness of pile cap	11 ft 9 in
Foundation of reactor building	Reinforced concrete raft 225 ft × 110 ft × 8 ft thick
Turbine hall overall dimensions	Approx. 385 ft × 155 ft wide × 94 ft high
Pumphouse dimensions	125 ft wide × 133 ft long
Circulating water flow	27×10^6 gal/h

An entirely new field in the technological applications of graphite materials has been opened up by the completion of this new pilot plant



Production of impermeable graphite

HAWKER SIDDELEY'S research and development on graphite was initiated by the need for improved graphite in high temperature gas cooled reactor systems. Successful development of the furfuryl alcohol process (see *Nuclear Power*, February 1959, p. 86–8) has now made effective impregnation practicable.

The pilot plant consists basically of two furnaces, one for carbonizing and another for graphitizing, vertically disposed within a semi-circular structure surrounding a loading bay (see picture at top of page, and Fig. 1). Machined graphite components are first impregnated with furfuryl alcohol or other impregnants after which they are lifted and inserted into the carbonizing furnace for treatment up to 1000°C. For particular customer requirements, where carbonization does not give specific physical, electrical and thermal properties, it is necessary to process further in the graphitizing furnace where temperatures up to 3000°C are reached.

The carbonizing furnace

The 1000°C controlled atmosphere baking furnace, designed by Sintering and Brazing Furnaces, is a vertical cylinder, 22 ft high and 8 ft 6 in dia., with a working space of 4 ft 6 in dia. by 14 ft 6 in deep. It uses an inert atmosphere which at present is nitrogen, having a maximum oxygen content at 10 ppm.

Batches of components, arranged on a loading jig, are lowered through the top of the furnace on to a work support spider by means of a three-ton hoist. Carbonizing is carried out in a muffle chamber fitted with re-circulation ducts. Beneath the spider is a fan which draws down the working gas through the charge, and exhausts through the ducts. The nickel-chromium tape heating elements are arranged in three zones, each identical and independent. The temperature of the work space is measured by selectable thermocouples, with additional thermocouples near the heating elements. Their output is taken to an instrumentation and control panel on the control deck from which furnace operation is automatically programmed.

Successful processing is completely dependent on fine temperature control. In some applications a slow steady cure of carbon products may take five days, during which time the temperature is raised steadily and accurately up to 1000°C. Any sudden change of temperature will ruin the product under treatment. The maximum temperature differential over the whole work space is only 10 deg. C.

The new process aims at achieving near impermeability to gases or fluids by reducing permeability a millionfold. At the same time, marked improvement in the mechanical, physical and thermal properties is also attained (Table 1). The treated material retains its low permeability at elevated temperatures and may be evacuated to less than 10 μm for several hours at 1800°C, under inert gas conditions.

TABLE 1 *Typical mechanical and physical properties of fine-grained graphite processed at Langley*

	UNTREATED	TREATED
Flexural strength, lb/in²	3600	5700
Elastic modulus, lb/in²	$1{\cdot}8\times10^{6}$	$3{\cdot}0\times10^{6}$
Electrical resistivity, milliohm—cm	1·9	1·5
Thermal expansion per deg C 300°C	$2{\cdot}0\times10^{-6}$	$2{\cdot}1\times10^{-6}$
600°C	$2{\cdot}2\times10^{-6}$	$2{\cdot}7\times10^{-6}$
900°C	$2{\cdot}6\times10^{-6}$	$3{\cdot}0\times10^{-6}$
Ultimate tensile strength, lb/in²	3200	5900

The graphitizing furnace

The 3000°C controlled atmosphere graphitizing furnace, four times larger than any similar furnace yet designed, is capable of accommodating graphite components up to 10 ft long. The charging area has a 3 ft 6 in dia. and is 10 ft long. The vertical arrangement offers not only the advantages of simple charging by means of a specimen cradle but also a lesser chance of long specimens bending during graphitization. Because of the high temperatures the interior of the furnace is fabricated from graphite, obtainable only in small pieces. The furnace is water-cooled and the metal expansion liner of the containment vessel which contains the insulation is provided with backing spring supports to cater for both hydrostatic loading and the thermal expansion of the insulation.

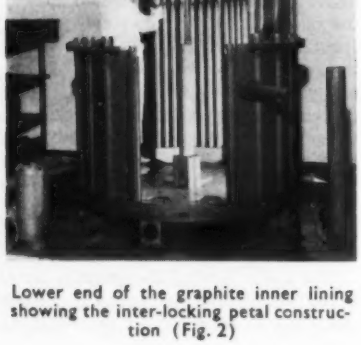
The machining of the many-shaped and varied components called for the use of several of the Graviner-designed special purpose machine tools. It was thus possible to machine the 7 ft dia. components as complete rings, whilst the radial slots, grooves and cut-outs were machined using a motorized radiusing attachment to a universal milling machine. Various grades of graphite were used dependent upon the functions to be performed by individual components.

The lower end of the graphite inner lining constitutes a furnace hearth made up from plates of inter-locking

petal construction pierced by 12 apertures for the graphite feed rods (Figure 2). The hearth is supported on 12 tubes which form the protective containers through which the element feeders project into the furnace's interior. These graphite feed rod guide tubes are made in three sections capable of movement to allow for differences in expansion.

The heating element consists of 196 graphite rods, of 6 ft length and 2 in dia. axially arranged and spaced circumferentially around the heating space. In view of the unusual depth of the furnace it was necessary to join two lengths of rod with graphite tapered sleeve connectors. The upper ends of the top set of rods enter apertures in a graphite ring which is also the neutral point of the 3-phase element. Three of the rods are anchored to the ring and the others are mounted to allow relative axial movement, good electrical contact with the ring being maintained by internally tapered collets. The lower ends of the rods are threaded into a graphite ring sub-divided into twelve separate sectors, making four sectors for each phase. Each sector is mounted on top of the graphite feed rod leading down into the water jackets, at the base of the furnace. These water jackets are insulated from the furnace vessel itself and are concentrically mounted below further jackets which cool the lower ends of the feeder containers.

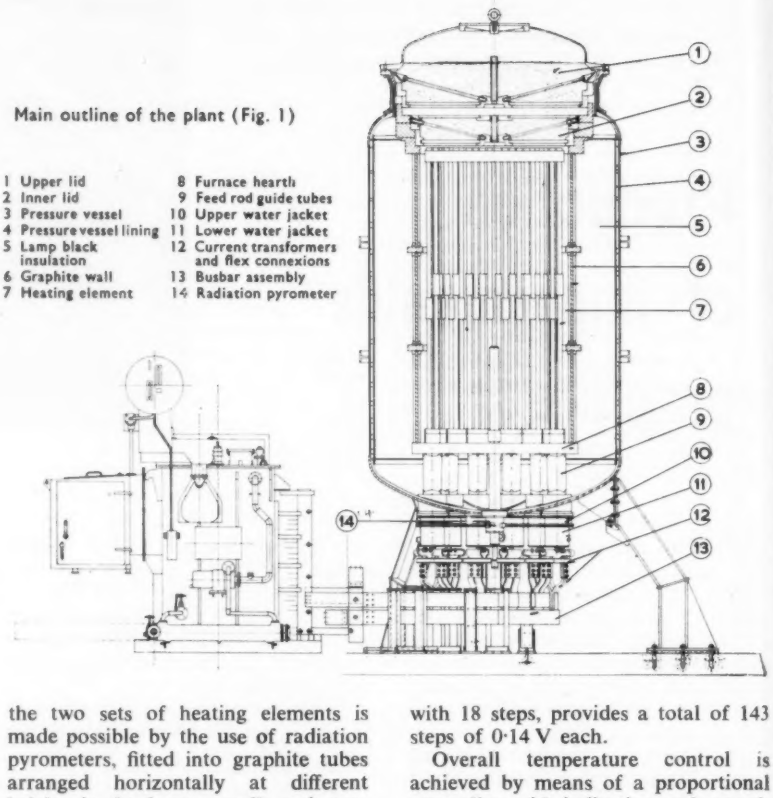
The heating elements are surrounded by a cylindrical wall built with vertical graphite rods slotted lengthwise to take the graphite plates. Each of these rods is made in three sections, with the ends of each section fitted into graphite sleeves which are themselves placed in holes in graphite rings horizontally surrounding the whole cylindrical wall. The furnace hearth forms the bottom closure to the graphite wall. Temperature determination of



Lower end of the graphite inner lining showing the inter-locking petal construction (Fig. 2)

Main outline of the plant (Fig. 1)

1 Upper lid
2 Inner lid
3 Pressure vessel
4 Pressure vessel lining
5 Lamp black insulation
6 Graphite wall
7 Heating element
8 Furnace hearth
9 Feed rod guide tubes
10 Upper water jacket
11 Lower water jacket
12 Current transformers and flex connexions
13 Busbar assembly
14 Radiation pyrometer



the two sets of heating elements is made possible by the use of radiation pyrometers, fitted into graphite tubes arranged horizontally at different heights in the furnace walls and passing through the main shell.

The furnace lid is constructed in two separate parts forming an upper and lower closure. This reduces the effects of convection and stray radiation and caters for as much as three inches of differential thermal expansion. The upper part is a metal cover secured by a metal ring with L-shaped graphite rings of decreasing diameter beneath it. The cover is closed at the bottom by interlocking graphite plates and has as its hub a graphite block joined by tie-rods to brackets fitted to the metal ring.

The lower part of the graphite lid which is hollow and filled with lampblack, has top and bottom plates of inter-locking petal construction. In spite of the complex assemblies forming the inside of the furnace, the concentricity of the top graphite ring to the inside diameter of the shell is within 0·060 in.

Control

Power is supplied to the elements at 25 V with a mains input of 6·6 kV. For the control of a loading of 800 kVA a tap changing transformer at 6·6 kV feeds into a furnace transformer, the two transformers being housed in a common tank. For fine regulation, a coarse tap changer is with eight steps and a fine tap changer with 18 steps, provides a total of 143 steps of 0·14 V each.

Overall temperature control is achieved by means of a proportional controller, with indicating and recording facilities, driving the tap changer mechanism. Manual push button control is also provided, to operate the tap changer in the same sequence.

The temperature control signal is derived from the total radiation pyrometer sighting at the element. A further radiation pyrometer is arranged through the second instrument at the base of the furnace, to indicate and provide a chart record of charge temperature. Thermocouples situated at various points in the overall system are fed to a 36-point precision self-balancing potentiometer to allow monitoring by the operator.

CONTRACTORS

SINTERING & BRAZING FURNACES LTD
Main contractors, manufacture of complete plant and installation design
SPEMBLY LTD
Design and commissioning graphitizing furnace installation
ARTEX (1931) LTD
Structural steelwork
F. H. DOWNS ENGINEERING CO.
Furnace sheet metal work
C. F. IDES ENGINEERING LTD
Graphitizing furnace pressure vessel
F. F. TREACHER LTD
Site preparation
R. F. WHEELER LTD
Plumbing
GRAVINER MANUFACTURING CO. LTD
Machining of graphitizing furnace graphite lining and elements
MORGAN CRUCIBLE CO. LTD
Supply of graphite raw material
BRITISH ACHESONS ELECTRODES LTD
Supply of graphite raw material
BRUSH ELECTRICAL ENGINEERING CO. LTD
Switchgear and design of electrical supply system
FULLER ELECTRIC LTD
Transformer

STUDENTS' NOTEBOOK

GROUNDWORK—Reactors

What is the procedure for obtaining a university reactor in the United Kingdom?

Some nine university research reactor proposals are under active consideration by the Government. Schemes which have reached an advanced stage in official deliberations are those submitted by the London University Imperial College of Science and Technology and the Queen Mary College. The joint projects of Manchester and Liverpool, and of the Scottish Universities, together with the proposals from Birmingham and Southampton, are also reasonably well advanced. Interest has also been shown by the Durham, Sheffield and Leeds universities.

The earlier proposals have been in hand for two years and, since building permission has been granted to both the Imperial College and Queen Mary College, it is reasonable to ask why there is a delay. The present procedure for complete approval, however, is somewhat complicated. The recent American decision not to finance further research reactors, the opinions expressed at the Gatlinburg Conference (see *Nuclear Power*, October, p. 99) and the UK attitude of reviewing requirements on a national basis, have all contributed to this delay.

The procedure for obtaining a licence to build, now laid down under the Nuclear Installations (Licensing and Insurance) Act, 1959, is in itself relatively uncomplicated. The details that are to be submitted to the Minister of Power constitute a general statement of intention and take the form of a preliminary safety submission. The main point to be demonstrated is that a nuclear accident involving direct radiation hazard or fission product release above the maximum permissible safe level is impossible in any foreseeable circumstance.

A brief description of the reactor system includes nuclear characteristics and a statement of the experiments to be performed. Included among site particulars are: the reactor's location; the owner; planning consent; local populations in most densely populated 10° sectors, and the total population; schools and other establishments up to a one mile radius. Medium and large industrial and military installations within five miles are also to be indicated. Cooling water requirements are to be specified and the nature of the heat exchangers described. The effect on water supplies has to be considered with details of effluent disposal particularized. Meteorological data include a record of the local wind direction and velocity over the year recorded as a time percentage, mean monthly rainfall figures and mean monthly fog frequencies.

The application is accompanied with a one-inch map showing the reactor site around which circles representing ¼, 1 and 5 miles radius are drawn, and a six inch map covering the area up to at least one mile radius from the reactor and the populations of towns of more than 1000 inhabitants within five miles.

The nuclear site licence, when it is issued, includes instructions covering the prevention of danger from ionizing radiations, medical examination of employees, operation and maintenance requirements and the storage and disposal of nuclear fuel.

The local council should be taken into confidence at an early stage, in fact they have to be approached at some time about proposed development plans that may affect the site. Local cooperation is an obvious necessity to the successful continuance of a private reactor proposal. The Minister of Power takes the necessary action that concerns other Ministries and keeps in close touch with the UKAEA on reactor safety questions.

The Department of Scientific and Industrial Research are approached for grants in the same way as requests for other university equipment. The proposal has to be justified by a detailed programme of research extending over at least three years. Unlike requests for similarly expensive research tools such as wind tunnels and accelerators, the decision to treat this matter at a national level involves the National Institute of Research and Nuclear Science who advise on the technical merits.

It is to be hoped that the Government will waste no more time over the deliberation on reactor proposals and will allow the Universities with serious intent to proceed with their important research programmes.

NEWS

Teaching engineers metallurgy Lively discussion followed Professor Ball's paper given in November at the Institution of Mechanical Engineers. After criticizing the inadequacy of the established treatment of metallurgy for engineers, he advocated greater cognisance of recent developments in the science of metals. Courses should be attractive and impart useful knowledge, he concluded.

Other speakers agreed that the old practice of the 'cookery book' treatment of facts were of no inherent value to anyone; it was also important to dispel the idea that metals are lumps of the same stuff throughout. The strongest possible emphasis was to be placed on educating the engineer in the nature of metal thinking so that, in his own environment, he could go part of the way towards meeting the metallurgist.

One should deal with fundamentals it was argued; mechanical, electrical, magnetic and thermal properties should all receive attention. The whole question of dislocations and plastic flow was important, even the unfashionable study of extraction metallurgy and fabrication was necessary for the engineer to make some sense of metal specifications.

In summing up, Professor Ball considered that students liked to have intellectual justification for what they were learning. It was therefore necessary to be ruthless in subject selection and to present things that were intellectually practicable and capable of justification.

- Philips service manuals, covering the company's current radio and television range, are to be made available to all of the main technical colleges throughout Britain.
- Vickers-Armstrongs (South Marston) Ltd will demonstrate their reactor simulator and laboratory neutron source at the Coventry Technical College at 3.0 p.m. on January 4, 1961.
- USAEC awards to educational institutions over four years now total over $M18. This assistance concerns 330 organizations and covers nuclear laboratory equipment.
- A 2 MeV Cockcroft-Walton accelerator, costing £40,000, has been purchased from the Cavendish Laboratory by the Potchefstroom University in South Africa, where it is to be re-erected.
- In November, Wales held its first major exhibition on atomic energy. Presented by the UKAEA, it took place at the Welsh College of Advanced Technology in Cardiff.
- The USAEC is to issue licences to the Universities of Washington and of Wisconsin for the operation of training reactors, a 10 kW AMF and a 10 kW GE type respectively. Another University, California, has recently installed an AMF 'Educator' reactor. Pensacola Junior College is installing a Lockheed 20% enriched subcritical plant.

UK COURSES

Ekco Electronics, Southend-on-Sea Applications of nucleonics in industry and research. Special two-week courses for the technical representatives of Ekco distributors.

Northampton College of Advanced Technology, London Fatigue of Metals and other materials. Heat Transfer II: Tuesday evenings for 10 weeks commencing January 10, 1961. Fee for each course: £3 3s.

Lanchester College of Technology, Coventry Theoretical physics: January 3 to March 21, 1961, Tuesday evenings. Fee: £1 2s. Recent Advances in Non-destructive Testing: February 23–24, 1961.

Nottingham and District Technical College Pumps and Compressors: Monday evenings for 12 weeks commencing January 2, 1961. Fee: 11s. The Engineering Uses of Radio-active Isotopes: Tuesday evenings for 10 weeks commencing January 3, 1961. Fee: 11s.

Harwell Reactor School Principles of Radiation Protection: advanced course, April 19 to July 18, 1961. Intended for graduates or persons of graduate standard. Fee: £250.

Points from Papers

reports, meetings, conferences

CONCRETE PRESSURE VESSELS

News that EDF is considering a prestressed concrete pressure vessel for the third station at Chinon reflects the current interest in this type of containment.

A report was given recently at a joint meeting of the Institution of Structural Engineers and the Société des Ingénieurs de France (British Section) of the G2 and G3 stations at Marcoule; both have this type of pressure vessel. Details of the design were given by M. Jean Bellier, the Consulting Engineer, and an account of the site organization and actual construction methods by M. Max Tourasse, Director of the Compagnie Industrielle de Travaux. M. Bellier gives a full and very readable account of the problems and the way in which they were tackled and overcome.

A design study for a concrete pressure vessel is given by Mr Davidson in a paper presented to the Institution of Civil Engineers. This reviews the problem of large steel pressure vessels and progress in the design and construction of concrete biological shields. Consideration of these two subjects leads to the proposal for a concrete pressure vessel.

Prestressed concrete pressure vessels at Marcoule Nuclear Centre. Jean Bellier and Max Tourasse. 28 pp. Published by the Cement and Concrete Association.

Some contributions from nuclear power to engineering practice. Ian Davidson. **Paper no. 6443.** 16 pp. Institution of Civil Engineers.

DOSEMETER CALIBRATION

Unit radiation exposure dose is referred to dry air of specified composition at 0°C and 760 mmHg. Most dosemeters are sensitive to ambient air conditions and corrections need to be made. Those for temperature and pressure have previously been made, somewhat laboriously, either by calculation or the use of nomograms. A useful critical survey has now come from the NPL giving four-figure tables of correction factors for a pressure range from 600 to 850 mmHg and a temperature range of 0° to 40°C. Also the best available correction factors for humidity variations over the range 0–100% are given; this should prove a valuable addition to precision dosimetry.

Effects of variations in the ambient air on the calibration and use of ionization dosemeters. G. P. Barnard, G. H. Aston and A. R. S. Marsh. National Physical Laboratory. 31 pp. Available from HMSO 2*s* 6*d* (USA 45 cents).

NUCLEAR SHIP COSTS

This report evaluates the design studies put forward to the US Joint Committee on Atomic Energy this year. They were prepared by Combustion Engineering Inc.—PWR; General Electric Co.—direct-cycle BWR; and Westinghouse Electric Corp.—indirect-cycle BWR. The designs were described in *Nuclear Power*, August 1960, pp 78–82. The Committee conclude that the direct-cycle BWR, because of its lower capital and operating costs and greater potential, will be the most likely system to achieve competitive power in the near future. The PWR is the second. The longer range potential cost reductions of the direct-cycle BWR lie mainly in the development of integral nuclear superheat. This will result in increased thermal efficiency and the decrease in propulsion machinery cost and weight. The possibility of further automation will reduce the size of the crew needed.

The report includes appendices on the cost analysis, technical analysis and future potentials of the designs.

3 design studies for selecting a prototype reactor for a nuclear tanker. USAEC. **Report TID-8528.** 67 pp. Available from OTS $1·25 or depository library.

THERMAL CONDUCTIVITY OF UO_2

Uranium dioxide, sintered and cold-pressed, is a promising ceramic fuel but suffers from the limitation of low thermal conductivity. The factors affecting this are not adequately understood and a series of in-pile experiments (WAPD-22) have been reported by Westinghouse's Bettis Laboratory. They were designed to determine the 'effective' thermal conductivity of UO_2 fuel elements as a function of diametral distance between fuel and cladding, the gas atmosphere in the gap and the central fuel temperature. the experiments were run in the MTR using mainly Shippingport PWR core 1 production pellets with a limiting amount of heat generation to preclude centreline melting. The report says that the thermal conductivity shows a marked sensitivity to the initial assembly clearance due to the thermal resistance of the gap. The initial atmosphere has apparently no effect. The possibility of increasing the thermal conductivity by the use of a purified oxide was also shown by the experiments. At temperatures above 500°C at a burnup of 4×10^{19} fissions/cc thermal conductivity was unaffected.

Measurement of the thermal conductivity of metal-clad uranium oxide rods during irradiation. I. Cohen, B. Lustman and J. D. Eichenberg. Bettis Atomic Power Laboratory. **Report WAPD 228.** 49 pp. Available from OTS $1·00.

IRRADIATION OF SANTOWAX-R

Experiments at Harwell on irradiation of Santowax-R are likely to have some effect on the design of organic-cooled reactors. Samples have been bombarded with fission fragments from thin foils of U_3O_8 in BEPO at 350°C. Data were collected of the gas produced, rate of polymerization, and fate of fission products. It is assumed that a failure of fuel element cladding, other than complete rupture, would not be as serious as in other types of reactor. Though information is not available of dynamic conditions, it is expected that failure would be followed by the formation of a stable coke film and that the fission products would diffuse slowly through this, after an initial release of activity.

Another serious consideration is the amount of acetylene found in the coolant. Accumulation at certain points in a reactor could present a serious explosion hazard.

The irradiation of Santowax-R with fission fragments. D. A. Landsman and A. E. Truswell. AERE Harwell. **Report AERE M715,** 22 pp. Available from HMSO 4*s*.

NEW USAEC NEWSLETTER

The newly established Neutron Cross Section Evaluation Center at Brookhaven National Laboratory has published its second newsletter. Each issue will contain a summary of the more important current information and will be published at irregular intervals. The first issue announced the setting up of the Center. Subjects covered in the current newsletter are: inelastic neutron cross sections; angular distributions; angular distribution at 3·7 MeV; fast neutron cross sections of oxygen and nitrogen; thermal neutron absorption cross sections; neutron resonance parameters; fast neutron activation cross sections; 0-16-(n,p)N-16; and computing machine codes.

Neutron cross section evaluation group newsletter no. 2 1960, BNL 634 (T-197). 8 pp. Available from OTS 50 cents.

CARBON TRANSPORT IN HELIUM

There is no reaction between ionized or excited helium and carbon which would be sufficient to cause a significant attack on the graphite in a helium-cooled graphite-moderated reactor. This is inferred from work done at Harwell on pyrolytic carbon films exposed to plasma generated by micro-wave radiation in a stream of helium, and from theoretical considerations.

On the possibility of irradiation induced transportion of carbon in helium. I. N. Onslow MacAuley and M. Tomlinson. AERE Harwell. **Report AERE R3262,** 15 pp. Available from HMSO 3*s*.

New Reports

Nuclear fusion, journal of plasma physics and thermonuclear fusion. A new journal published by the IAEA. Annual subscription (4 issues) 70*s*.

Comparison test of reinforcing steels. AEC report WT-1473. 108 pp. Available from OTS $2·25 or depository library.

Creep and rupture properties of carbon steels. A. I. Smith, E. A. Jenkinson and D. J. Armstrong. Preprint 1/60. Institution of Mechanical Engineers.

A new description of thorium spectra. R. Zalubas. NBS monograph 17(1960). Available from Superintendent of Documents, US Government Printing Office, Washington 25 DC, $0·65.

Supplement one to list of publications, Sept. 1959 to May 1960. Atomic Energy of Canada Ltd. Available from Scientific Documents Distribution Office, Chalk River, Ontario.

Selected abstracts of atomic energy project unclassified literature in the field of radiation chemistry, and bibliography of the published literature, 4th annual supplement (papers noted to Dec. 1959). Compiled by R. W. Clark. AERE Harwell. **Report AERE C/R 1575 (1-6) Supplement 4,** 497 pp. Available from HMSO 64*s*.

Aluminium for nuclear power

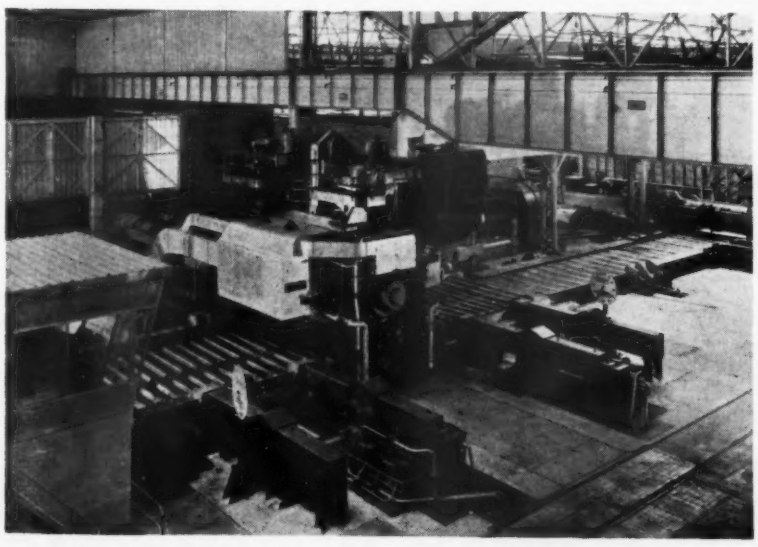
new continuous strip mill

FOR THE PURPOSE of expanding its aluminium production facilities, Alcan's main effort at its Rogerstone works is concentrated on improvements to the existing continuous strip mill. When the work is completed the nominal output of sheet and strip will be raised from 50,000 tons to 70,000 tons a year, together with a substantial extra capacity for hot-rolled coil and plate. A larger proportion of the output will be made from the stronger alloys, in addition to aluminium alloy plate in greater widths than hitherto available.

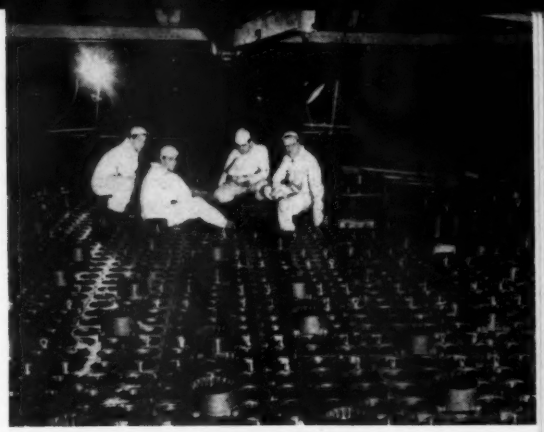
The plate, to a maximum width of well over 10 ft, and up to 50 ft long, will be rolled by the new 144-in hot mill. Less joining will therefore result at reduced costs to the user. Other equipment has been installed to shear and handle the wide plate. A new ingot tilter is fitted to the tables between the shear and the mill to load ingots from the tunnel furnaces for rolling while the plate just rolled is being sheared and lifted from the tables.

Nuclear applications which are likely to benefit from the use of the larger plate include storage tanks for light and heavy water, hydrogen peroxide and uranium tetrachloride, carbon dioxide and helium. Aluminium requirements for Capenhurst's diffusion plant extensions have been estimated at 15,000 tons, mainly in the form of heavy plate, sheet and forgings. It is also possible to produce larger diameter ends for pressure vessels without recourse to welding. For pool type reactors, there is a requirement for the core shell, the pool liners, low temperature heat exchangers and decay tanks. Another possible application might be its use for the storage of radioactive waste that can be dumped in the sea or buried underground.

★ 280



ALCAN's 144-IN MILL is driven by two 4000 h.p. single-armature d.c. motors arranged in the 'top-forward' configuration. The control cabin (in the foreground) is set beside the entry tables, and mill operations are recorded by large dials set at a low level on the line of sight to the mill. Run out tables lead to the 4-in slab shear, seen in the background



BRADWELL CHARGE PANS. In the above view, across the top of No. 1 reactor core, engineered by Head Wrightson, the installation of the charge pans is being completed. Two of the working group, Italians, are receiving instruction in readiness for Latina. A charge pan consists of small steel castings bolted between a top and bottom steel plate. Each of the 178 pans is provided with 18 tapered holes matching the fuel channels, one of the holes carrying a sleeve to take the control rod guide tube. Access into the reactor vessel for fuel charge/discharge is by way of standpipes. The charge machine manufactured by Strachan & Henshaw, is already in operation, the standby machine is being assembled ★ 281

High voltage circuits

relays replaced

To overcome the insulation problem in the use of electromagnetic relays in monitoring devices on circuits at very high voltages, a Harwell invention replaces the relay by a beam of light and a photocell. The beam is produced by a neon glow-discharge tube inside a plastic housing which defines the path for the light beam, acts as insulation and excludes external light.

In one application, the device operates satisfactorily with as much as 8 kV between the neon tube and the photocell; the low voltage relay being near to earth potential presents no insulation problem. For use at higher voltages where the distance between the neon cell and photocell has to be increased, a light-guide of glass or methyl methacrylate rod can be inserted to give better light transmission.

★ 282

Packing fuel elements

vibration compaction

A new method of packing fuel elements by vibrational compaction, is being used by General Electric at the AEC Hanford Plant. By simultaneously compacting and cladding ceramic fuel materials, the process is expected to make substantial saving in the cost of fuel element fabrication.

The system uses a vibrator driven by a large electromagnet delivering a thrust of nearly 5000 lbf, and a

24,000 W amplifier. Fuel element cladding in the form of tubes up to 8 ft long are attached to the vibrator and, as fuel powder is poured into them, the tubes vibrate at frequencies ranging from 5–5000 c/s, thereby compacting the fuel to 90% of its theoretical density in about three minutes.

Accelerations of more than 100 *g* have been applied to the tubes without dimensional changes or other adverse effects. Fuel rods with walls as thin as 0·005 in have undergone compaction without damage. ★ 283

Temperature scanning
for Trawsfynydd

In its early design stages is the temperature data handling equipment to be manufactured by Blackburn Electronics. Intended for Trawsfynydd, it will operate continuously, scanning some 670 temperatures covering the fuel elements, coolant and ancillary circuits, etc.

Each of these 670 temperatures will be checked every 70 seconds for any departure from the normal operating levels, and at the same time, identifying the particular temperature involved and the extent of the deviation. In addition, a printed record of all the temperatures is provided at regular intervals, together with a note of the time of the reading. The equipment checks itself at every scan, giving a warning of any fault.

★ 284

Magnox/stainless joined
gas welding process

For the first time, Magnox and stainless steel have been joined, by the use of 'Tinflux', a gas-welding process developed by British Oxygen Gases in cooperation with the UKAEA.

The present application by the UKAEA, is carried out on special bolts used to secure fuel cans in position for deadweight load and pressure tests. Bolt stems of stainless steel are fitted with Magnox bushes under the heads. A 'welded' seal is made between the bushes and the bolt heads. Recesses in the bushes form joints with the tops of the cans and act as vacuum-tight seals during testings.

British Oxygen Gases oxy-acetylene lightweight 'Saffire' blowpipes are used for the joining operation.

★ 285

Concrete structures
economy in formwork

Simple devices have been used in the early construction stages of Hinkley Point and Berkeley that have resulted in saving time on site work. 'Rawlties' and 'Rawloops' manufactured by The Rawlplug Co., support shuttering or framework for concrete and allow successive lifts within a few hours. In addition they can be made to support platforms for the dressing of concrete, safety rails, grids and site lighting.

The 'Rawlties' are used in the construction of vertical walls and structures where access to both sides of formwork can be obtained. 'Rawloops' are for use where access can only be obtained to one side of the framework; when special structural shapes prevent the use of both sides, or for cantilevered shuttering. Another product 'Rawlhangers' are especially designed to give support to formwork from steel beams. ★ 286

AI's REACTOR SAFETY DEVICE. A self-contained automatic shut-down fuse, designed to provide additional control in certain types of experimental reactors, the Maritime Gas-cooled Reactor Critical Experiment in particular, has been designed by Atomics International. Part of the cylinder is inserted in the core, the part outside contains boron trifluoride gas. In the event of a power surge, the gas is released by the trigger element from the high pressure area into the other part of the cylinder. The gas absorbs neutrons and brings the reactor under control almost immediately and without damage

1 high pressure 2 intermediate pressure 3 burst diaphragms 4 spacer 5 capillary fill tubes 6 release tube 7 trigger element 8 uranium 9 solder 10 monel

★ 287

IN BRIEF

Improved beryllium Lockheed are looking into the possibility of improving the mechanical properties of beryllium by electron bombardment melting. Their programme aims at the production of uniform and defect-free ingots.

★ 288

Automatic radiation counting For operation under field conditions, Baird-Atomic have designed a 38-ft trailer-laboratory capable of handling 150 radioactive samples automatically. Keyed to an IBM accessory instrument, the installation consists of six gamma/beta scintillation spectrometers with automatic sample changers.

★ 289

Pipe inspection It is now possible to use a Pye television camera for probing cracked or blocked drainage pipes down to a diameter of 8 inches. The new equipment, which has a built-in lighting system, is pushed through the pipe by means of a rod.

★ 290

Temperature measurement For the measurement of temperatures above 1000°C, but with a tenfold increase in accuracy, the Australian Scientific and Industrial Research Organisation have developed a pyrometer that uses a photo-electric system.

★ 291

Oxygen lancing During a shut-down maintenance of Chapelcross, a stud bolt in the main blower casing was found to have seized. For speedy removal, a BOC 'Saffire' combined cutter, with a $\frac{1}{16}$-inch nozzle, and an oxygen lance, fitted with a $\frac{1}{4}$-inch gas barrel, were used.

★ 292

Dual-purpose detector Intended for radiological defence, the International Civil Defence Organization have developed for large-scale use a portable instrument that combines in a single package a transistorized radio receiver and a radiation detector. A dial converts the radio set into a low-range or high-range geiger counter with calibrations—0 to 50 mr/h and 0 to 250 r/h.

★ 293

Porous filters Bound Brook Bearings have developed a process for the manufacture of porous p.t.f.e. filter elements with accurate pore size control, the sizes of particles filtered ranging from 5 to 60 microns. Porosity is not only of controlled shape, but also of controlled size, thus resulting in higher flow rates, lower pressure drops and good cleanability for a given fineness of filtration.

★ 294

Graphite impregnation A process is described in US Patent 2,946,699, for impregnating graphite with uranyl nitrate and heating the graphite until the salt is converted into an oxide.

★ 295

Image intensifier A five-stage intensifier tube, developed by 20th Century, has an overall light gain of 50,000 with a picture size of one square inch and a resolution of 14 line pairs per mm.

★ 296

★ *For further information on any item, circle the appropriate number on the reply card facing page 134.*

TOMORROW'S PEOPLE Schoolchildren with an eye on the future take a close look at the AEA's successful 12 day 'Atoms at Work' exhibition held at Cardiff recently. The exhibition was previously at Edinburgh where it had an equal fascination for children and adults

People

by John Radford

AS EXPECTED, the successor to **Sir Leslie Gamage** as chairman of the General Electric Company is to be **Mr Arnold Lindley,** at present vice-chairman and managing director. Mr Lindley takes up his new appointment at the beginning of next year and will continue to hold the post of managing director. A believer in field training for future executives, Mr Lindley joined the GEC in 1918 and in 1932 went to South Africa to become

A. LINDLEY
GEC head

T. E. GREENFIELD
sales development

chief engineer of the British General Electric Company of South Africa. In 1949 he returned to the UK as general manager of the heavy mechanical engineering works at Erith, becoming a director in 1953.

The post of sales development manager of the Industrial Process Control Division of Gresham Automation Ltd goes to **Mr T. E. Greenfield** who has been intimately connected with electronic research and development since the end of the last war. He was head of quality control for the production of guided weapons at English Electric's Stevenage works and has devised instrumentation methods applicable to industrial processes as well as a number of research projects.

The new deputy director of the CEGB's Berkeley Nuclear Laboratories is **Dr A. Trevor Churchman.** He still continues as head of the Materials Division of the new laboratories where work will be concentrated in three main divisions—Materials, Physics and Engineering. Before joining the CEGB in 1959, Dr Churchman was at the AEI Laboratories at Aldermaston and from 1955–58 was attached to Professor Cottrell's Irradiation Study Group at AERE, Harwell.

A key figure in the Wayne Kerr microwave design team, **Mr Barry Rogel,** has left Wayne Kerr Laboratories Ltd to become managing director of the newly formed subsidiary of the Rosemount Engineering Company of the US. He will continue, however, to act as consultant to Wayne Kerr and in this capacity joins **Professor A. L. Cullen,** Professor of Electrical Engineering at Sheffield University and **V. S. Griffiths,** reader in spectroscopy at the Battersea College of Technology. Recently, Mr Rogel made a special study of the measurement of semi-conductor parameters to extend the use of Wayne Kerr transformer bridges.

The drive to stimulate exports through the formation of the Export Council for Europe has gone a step further with the appointment of **Sir William McFadzean** as chairman. Sir William is the president of the Federation of British Industries and Managing Director of British Insulated Callender's Cables Ltd. Soon after accepting the chairmanship, Sir William announced the formation of his 16 member council which includes **Mr A. M. Browne,** vice-chairman, BEAMA.

Mr Derek R. R. Dick, formerly with the UKAEA and now a partner in W. S. Atkins and Partners, has been seconded to Richard Thomas and Baldwins Ltd to work as construction manager at the Spencer Works. This is the integrated iron and steel plant being built near Newport. Now 48 years of age, Mr Dick

D. R. R. DICK
construction manager

E. E. JONES
managing director

joined Atkins and Partners in 1955 from the AEA. From 1946–1955, he was actively engaged on most of the atomic energy projects in the UK.

An executive realignment has resulted in **Mr Eric E. Jones** becoming managing director of Adrema (Holdings) Ltd, one of the UK's leading manufacturers of business machines and systems. At the same time, he will become European vice-president of the Farrington Manufacturing Company, Massachusetts, the parent company of Adrema (Holdings) Ltd. Mr Jones was formerly group commercial director of the Solartron Electronic Group Ltd and succeeds **Mr Robert Cranston,** who is retiring.

Recent new appointments include: **R. V. Moore** and **Dr H. Kronberger** as deputy managing directors of the AEA Development and Engineering Group and **E. M. Summers, L. Rawlins** and **C. H. Wilson** as directors of The Stanton Ironworks Company Ltd.

New Product Survey

EQUIPMENT · INSTRUMENTS · MATERIALS

PLUTONIUM SPECTROMETER

gridded ion chamber

A new high resolution chamber designed by Intertechnique for alpha plutonium spectrometry has a resolution better than 0·5%. The complete equipment, marketed in the UK by Miles Hivolt, comprises a gridded chamber, a pre-amplifier, a vacuum pumping and measuring unit, a gas bottle for argon/methane mixture, and interconnecting cables for e.h.t. and input to a suitable pulse height analyser.

The pre-amplifier used with this equipment is of the cascade type and has an

Intertechnique's gridded ion chamber spectrometer, type S14, for plutonium alpha spectrometry

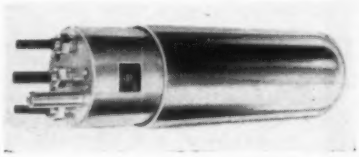
extremely low noise level. Background count between 4-6 MeV is of the order of one count per hour. Samples can be changed quickly and the chamber has been designed for easy decontamination.

★ 208

NEUTRON FLUX MEASUREMENT

ionization chambers

Based on Harwell design, but with a number of improved features, Plessey Nucleonics are producing two new neutron detectors, the PNI 1026—a two-electrode chamber and the PNI 1025—a three-electrode version incorporating gamma compensation. The 1026 chambers are to be installed at Berkeley.



Plessey's type PNI 1025/1 neutron detector is gamma compensated, has low residual activity and excellent saturation characteristics

All major components are made of high purity aluminium, with internal insulators and electrode supports of alumina, and vacuum lead-through seals of the ceramic-to-metal bonded type. The chambers, which are normally filled with hydrogen at pressures of 25, 75 or 225 cmHg, may be operated at temperatures up to about 200°C, the precise upper limit depending on the lower limit of current to be measured and the filling pressure.

The chambers show excellent saturation characteristics and low gamma sensitivity. Low residual activity enables a wide operating range to be covered.

★ 209

SIGNAL LEVEL RECORDER

high speed operation

Bruel and Kjoer's level recorder type 2305, available from B & K Laboratories, enables the accurate recording of signal levels in the frequency range 10–200,000 c/s within 0·2 dB as well as D.C. It will also record any voltage level between 5 nV and 100 V. Typical fields of application are the recording of frequency response characteristics, reverberation decay curves, and noise and vibration levels and spectrograms.

Among the design features are three full-wave rectifier circuits enabling true r.m.s., average and peak detection of the input signal to be obtained, and the incorporation of two writing widths of 100 mm and 50 mm. Each paper width has fifteen writing speeds.

★ 210

RADIATION COUNTING

double tracer studies

A new amplifier-analyser unit from Baird-Atomic, the 250, permits gamma scintillation counting as well as standard integral and differential counting. The technique of wide window integral counting is used which combines some of the background reduction properties of differential counting with the simplicity of integral counting. By setting the upper level control above the highest gamma energy of the isotope in use, an integral spectrum without high energy background can be obtained with the lower level control.

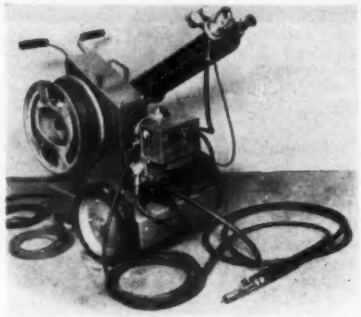
The new unit can perform double tracer studies with two scalers by using the integral output for counting gamma rays above the upper level setting, while the lower energy gammas are counted differentially in the window.

★ 211

POROSITY FREE WELDS

semi-automatic process

The Comet Series II process for semi-automatic welding, introduced by Rockweld, is claimed to be the most economical and practical method on all applications for plate thicknesses of ¼ in. and



The new version of Rockweld's Comet welding equipment can be supplied by any a.c. or d.c. welding power source of sufficient capacity

above. It is capable of providing welds completely free from porosity, on rusty, or even scaled, steel plate.

The equipment, which is transportable, now incorporates the CO_2 cylinder. Two alternative sizes of wire spool are permitted, 12 in. and 16 in., and by means of the tension device in the wire drum, and an improved feed box, one coil after another can be fed in, thereby eliminating wastage of 15 ft of welding wire.

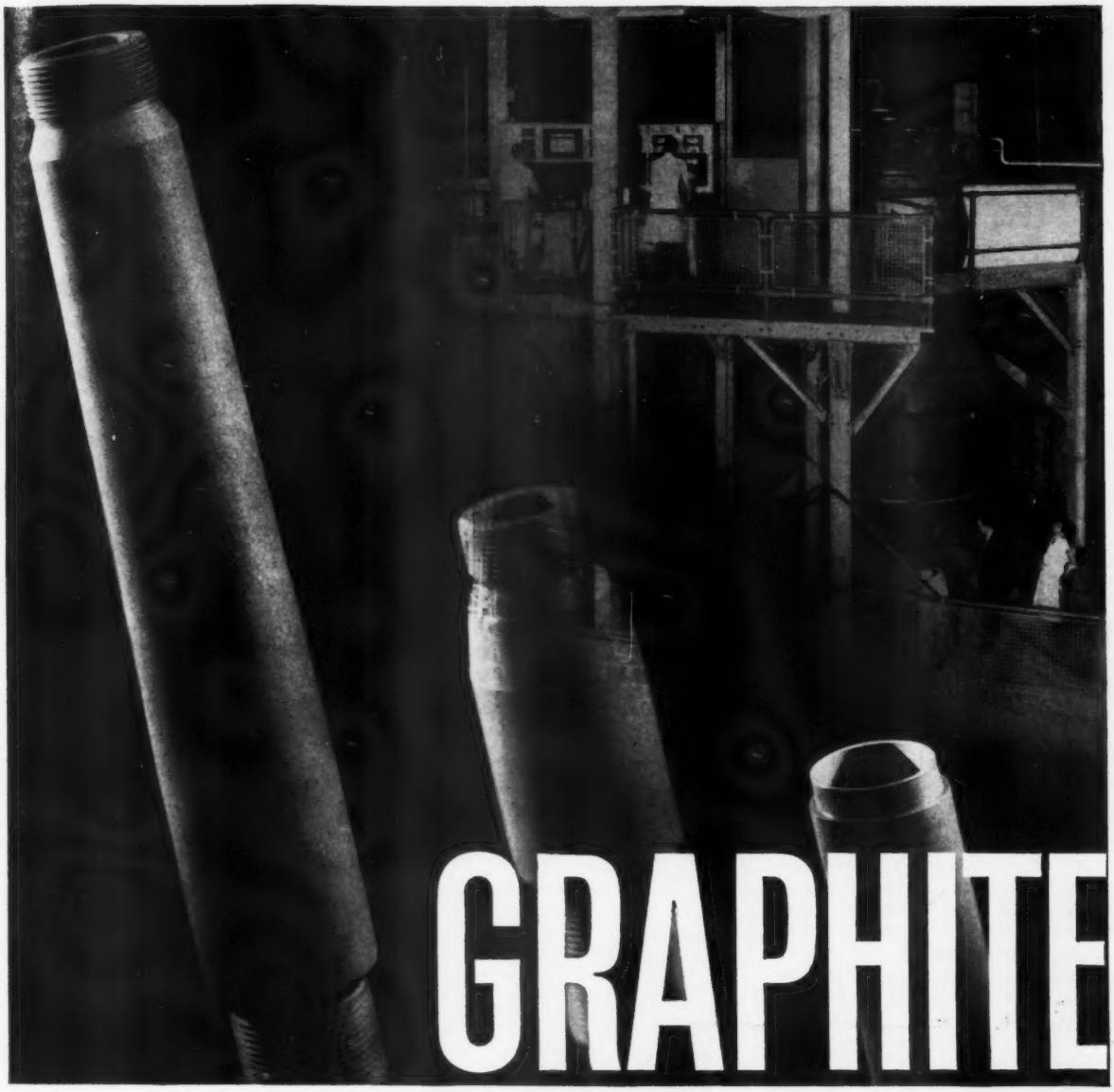
★ 212

GAMMA SOURCE

portable container

A lead-lined container for gamma-ray sources, designed to hold 5 curies of iridium 192 or 2·5 curies of caesium 137, is available from Solus-Schall. The intensity of radiation at one metre from the source is 6 milliroentgen per hour, when the container is closed.

The container can only be carried by the handle when it is in a locked and safe position. For operation, a padlock is removed; the handle can then be lifted to rotate the axis on which it is fixed.



PAR EXCELLENCE

OBTAINABLE FROM THE NEW GRAPHITE PROCESSING TECHNIQUES AT LANGLEY

Natural Porosity to gases and fluids is no longer a major disadvantage.

Hawker Siddeley Nuclear Power Company's processes broaden the field of Graphite usage in industry. The new material has an impermeability to gases which shows a millionfold improvement over normal grades — an improvement which is consistent and independent of temperature. Physical and mechanical properties are twice as good and the oxidation rate may be greatly reduced. This denser material permits appreciable reduction in the physical dimensions of future nuclear reactor systems for power generation. Corrosion-resistant and oxidation-resistant grades are eminently suitable for application in the chemical industry and in equipment for handling molten metals. Already, specific uses in appropriate environments include crucibles — particularly for handling rare metals — high temperature dies, bursting discs, pump seals, gland packings, rocket nozzle components and high temperature bearings and bushes. It is also used in the manufacture of transistors.

If you have an intractable materials problem, contact:—

HAWKER SIDDELEY NUCLEAR POWER CO. LTD

Sutton Lane, Langley, Bucks, England. Telephone No. Slough 24451 MEMBER OF HAWKER SIDDELEY GROUP

The Solus-Schall gamma source container, with cover removed, is in the firing position. The handle, which is in the non-carrying position, is brightly coloured and bears the word 'danger'

By doing this the gamma source, which is held in a protective sphere, is brought into position to emit radiation forward. The container normally carries a front cover with the centre hole plugged by a rubber pad. Total weight is 25 lb and overall dimensions are $6 \times 6 \times 7$ inches.

★ 213

DIGITAL DATA RECORDING

tape transport mechanism

For use with their analogue-digital computing system, Redifon have developed a magnetic-tape transport mechanism that moves the tape past the recording and reading heads in small separate steps, instead of continuously. It permits controlled variations to be made independently in the speed of recording data and the speed of reading-out data. Controlled variations can also be made in the time delay produced by the passage of data from the recording heads to the reading heads.

The tape transport mechanism, of which there are two in the recording equipment, uses 35 mm tape with sprocket holes, and this is moved past the recording and reading heads by two driving sprocket wheels. Up to 1000 ft. of tape can be stored on reels, or, for certain applications, the tape can be in a continuous loop up to 40 inches long.

The tape is moved forward solely in discrete intermittent steps during recording or read-out operations. This is done by a stepping motor, actuated by successive electrical impulses, which drives the sprocket system and so advances the tape in steps past the recording or read-out heads. A speed-reduction gear is used between the motor and the sprocket system.

The 35 mm tape is wide enough to accommodate 16 recording tracks side by side. This allows the recording of data elements in parallel or the simultaneous recording of several channels, using as many recording tracks as there are orders of digits or channels.

Digital input signals can come from a digital typewriter or any other suitable device. An analogue-digital converter incorporated in the equipment allows analogue inputs to be used as well. Tape speed control signals can be generated by an internal variable-frequency pulse generator or can come from an external source (a useful activity because it enables mathematical integration independent of time to be performed when the equipment is used as part of a computing system). The delay interval can be set by a manual control on the recording equipment, or, again, can be controlled by external means.

★ 214

IN BRIEF

• **Portable oscilloscope.** Solartron's miniature double-beam instrument CD1014 has DC to 5 Mc/s bandwidth (3 db) and two channels, each with sensitivity of 1 mV/cm. The instrument weighs 22 lb.

★ 215

• **Spot-welding torch.** The new British Oxygen argonarc spot-welding torch, S.W.300, is water-cooled and can carry up to 300 amps. Interchangeable nozzles and a button type micro-switch in the handle, allow welds to be made with one hand in horizontal or vertical positions, on narrow flanges or on 90° outside bends.

★ 216

• **Wide-band oscilloscope.** EMI's WM16 instrument has a bandwidth of DC-40 Mc/s, a fast rise time of 10 mμ5, sensitivity of 50 mV/cm and versatile sweep facilities.

★ 217

• **Pressure control.** Developed for use at Dounreay, Calder Hall and other nuclear plant, Negretti and Zambra's pressure amplifiers enable a number of small pressure fluctuations to be recorded and controlled at one point.

★ 218

• **Radioisotopes.** US Nuclear can provide gamma, neutron and positron sources from all commercially available species. These include plated gamma sources Ag-110, Fe-59 and Fe-55; Ra-Be, Sb-Be and Po-Be neutron sources; and Na-22 and Co-57 positron sources.

★ 219

• **Graph plotter.** A new automatic machine, Model QL, has been introduced by Benson-Lehner that enables a quick look at digitally recorded data on punched cards or tape at equal intervals of an independent variable. As many as 12 variables are plotted simultaneously at rates up to 2400 points/min.

★ 220

• **Air compressor.** Atlas Copco's TT6 'power pack' compressor is a two-stage, single acting machine with an intercooler built for a working pressure of 100 lbf/in² and a free air delivery of 140 c.f.m. It weighs 1050 pounds.

★ 221

• **Ultrasonic cleaning.** A new system has been introduced by Branson Instruments for processing small parts and sub-assemblies. The LG-75 unit, which is transistorized, is powered by a 75 W 'Sonogen' generator.

★ 222

• **Phase meter.** For the practical demonstration of circuit theory, feedback, mechanical and electrical resonance, Dawe Instruments have introduced the 630 transistor phase meter. It is designed to measure the difference in phase angle between two signals in the range 1 c/s–25 kc/s having inputs 0·03 V–300 V.

★ 223

• **Illuminated switch.** A new Square D product, 9001 Type TP, takes the form of an illuminated push-button switch which combines the functions of a double circuit switch and transformer type pilot light in one compact unit.

★ 224

• **Thermocouple joints.** Quick and easy connexion of thermocouple ends to extension lead wire is possible with West Instrument's new oil-tight plug-and-socket. Materials are used that prevent spurious e.m.f's.

★ 225

• **Variable transformer.** A new toroidally-wound ½-amp, 120 W unit, developed by Philips and marketed by Research and Control, provides an output voltage continuously variable from zero up to 250 V at a nominal current of 500 mA.

★ 226

• **Bi-directional transistors.** RCA have introduced two new composite-emitter-collector-type transmitters in the Jedec T0–5 package for medium speed switching applications. The emitter and collector can be interchanged, thus permitting either electrode to be used as the input or output electrode.

★ 227

• **Positive displacement pump.** Suitable for oils and greases, corrosive and abrasive liquids, Neumo's 'Supaversal' air operated pump can be supplied in any length of 8½ in to 12 ft. Its maximum capacity is 130 gal/hr for liquid delivery up to 1000 lbf pressure.

★ 228

• **Corrosion protection.** For steelwork subject to aggressive industrial atmospheres, Secomastic have introduced a new protective paint known as the Galvafroid-Micanox system. The first, a zinc-free compound primer, confers cathodic protection, the latter is micaceous iron ore paint which is chemically inert and resistant to ultra violet light.

★ 229

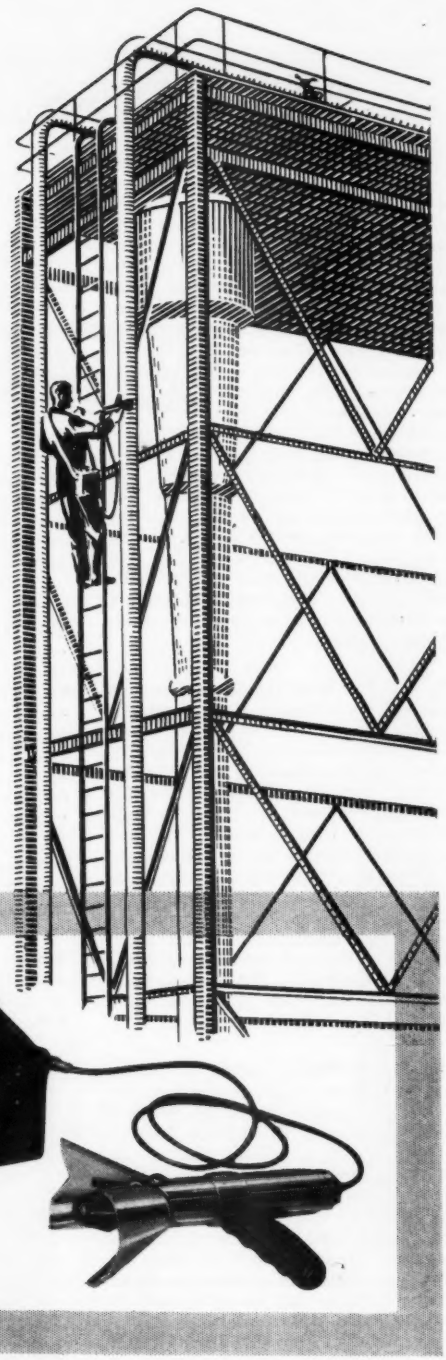
• **Digital register.** For automatic plant supervision where more complicated computor systems are not justified, Radiation have developed the 'Surveytron'. Based on the Kienzle transistorized digital printer, it integrates pulses from measuring instruments and initiates printing at pre-set times in some or all the channels.

★ 230

corrosion detection in boilers and pipes

N563 Metal Wall Gauge

the safe, reliable, cost-saving way!



Accurate detection and measurement of corrosion can be a costly and sometimes hazardous problem. Now with the new Ekco N563 Metal Wall Gauge it ceases to be a problem at all. This completely self-contained unit is specially designed for the task—and due to extensive use of transistors and printed circuits it is extremely light as well as absolutely reliable.

- *Measures the thickness of pipe walls where access is available to one side only.*
- *No special surface preparation of any kind is required.*

This is the modern, efficient, cost-saving way of measuring corrosion.

Write or 'phone for full information and literature.

EKCO nucleonic gauges

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BUSINESS NEWS

ON-OFF MERGER A brief statement by the boards of **English Electric** and **General Electric Company** put an end to plans for what would probably have been the most powerful electrical group in Europe. It said the boards had been unable to bring to a successful conclusion their discussions on a merger of the two groups through a holding company. Accordingly, the negotiations had been discontinued. No reasons for the breakdown in talks, which first started in September, were given. It is believed, however, that agreement could not be reached over the question of shares. The first announcement on the talks said the groups had been considering the position of the electrical industry and felt that many activities of their groups were complementary. They agreed to explore the possibility of a merger through a holding company.

PYE BUILDS REACTORS A licensing agreement for the manufacture and sale in the UK and Eire of research and training reactors has been concluded between **American Machine and Foundry** of the US and **Pye Limited.** Under this agreement, Pye will be able to provide British and Irish hospitals, research centres and colleges with a fully-developed series of low-power reactors and the related equipment plus engineering and design services. The two firms, the joint announcement said, would probably extend their co-operation to cover the Commonwealth, UAR, Iraq and Jordan. Pye has made AMF electronic manipulators for the last four years.

DUNGENESS VALVE ORDER **J. Blakeborough & Sons Ltd.** of Brighouse, have received an order from **The Nuclear Power Group** covering the main gas duct isolating valves for the reactors at Dungeness nuclear power station. These valves (16 in number) will be of the Blakeborough 'Stress-Seal' Butterfly type, 78 in. bore, with electric motor operation. Though larger in size, the valves are basically similar to those already supplied for Berkeley and in hand for Tokai-Mura.

HINKLEY CONTRACT AWARD A contract worth £30,000 for the production of special magnetic amplifiers for use in the reactor control system at the Hinkley Point nuclear power station has been placed with **Ultra Electronics Ltd.**

METALLURGICAL SPECIMENS OFFER **Weston Electric Units Ltd** of Lancs. are offering a complete service for the production of metallurgical specimens and are at present engaged in this work. The company points out that a monitoring programme for a single nuclear power station, for instance, can require more than 10,000 impact and tensile specimens. It adds that the problem of contamination has been overcome by laying down a production line of saws, shapers, millers and grinders in a new self-contained factory, devoted entirely to this work.

VALVE ASSOCIATION COMES OF AGE Valve exports were now running at an annual rate of £14 million, says the chairman of the **British Valve Manufacturers' Association (BVMA)** in his report to the 21st annual general meeting. However, he did point out that those companies whose exports were at present small, could significantly help in increasing the total of exports. He urged that manufacturers should aim at exporting 25% of their output.

BERYLLIUM MONITOR ORDERS Export orders totalling £15,000 have been received from the United States, France and Japan for the beryllium monitor manufactured and marketed for **Winston Electronics Ltd** and developed by the UKAEA. The equipment detects and automatically records the quantity of beryllium dust in workshops where beryllium metal and its alloys are worked.

• **X-Ray Engineering (London) Ltd** has opened a new X-ray Laboratory for the inspection of plastics.

• **Cape Insulation and Asbestos Products Ltd** is a new subsidiary company set up by **The Cape Asbestos Company Ltd** to take over management of the thermal-insulation, packings, jointings and textile side of their business from January 1, 1961.

• **Johnson, Matthey & Co. Ltd** has acquired control of the Swedish precious metal company, A/B Gosta Nystrom of Stockholm. The company is to be known as **A/B Nystrom & Matthey.**

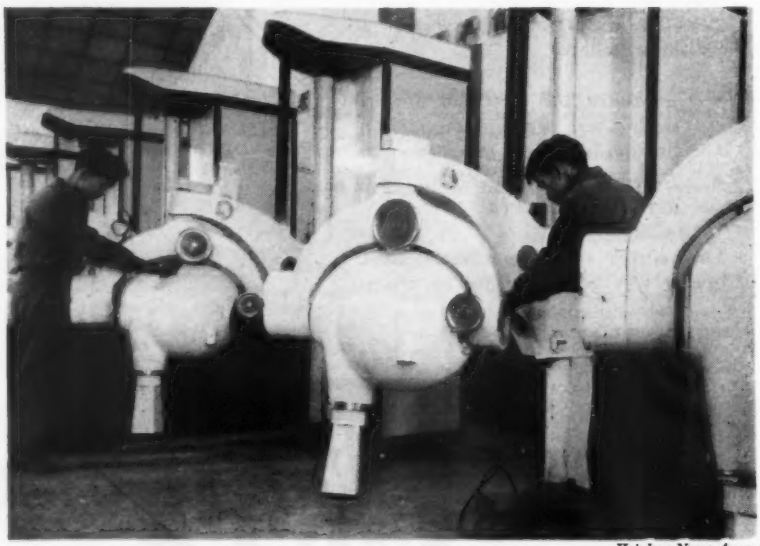
• **Continental Distributors Ltd** is marketing a range of radiation warning signs, the first two types being in the form of a continuous roll of cellulose tape.

OVERSEAS

NEW AEC CHARGES FOR PLUTONIUM From January 1, 1961, US companies leasing plutonium for commercial and industrial purposes will have to pay higher prices. The prices, the **AEC** announced, will be the same as the Commission paid for plutonium—$30–$40 per gram, depending on the Plutonium-240 content, for the period January 1, 1961–June 30, 1962 and $30 per gram, regardless of Plutonium-240 content, for the year July 1, 1962–June 30, 1963. The base charge for plutonium of unspecified Plutonium-240 content would be $30 per gram until June 30, 1963. The AEC added that neither buying nor leasing prices had been established beyond June 30, 1963, nor had charges been set for use of plutonium as fuel for reactors.

• The third highest sales in company history have been recorded by **North American Aviation Inc.** The company's Atomics International Division, the 1960 report points out, made marked progress.

• **Elliott-Automation AG** has moved into new offices in Zürich at 23 Holbeinstrasse.



Hsinhua News Agency

CHINESE MEDICAL EQUIPMENT Workers at the Shanghai Precision Medical Equipment Factory put the finishing touches to cobalt-60 beam therapy machines. The factory recently began small scale production

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Diary

10–12 JANUARY
Physics of Polymers, including Irradiation effects, conference, University of Bristol. Details, the Secretary, The Institute of Physics and The Physical Society, 47 Belgrave Square, SW1

16–20 JANUARY
Physical Society Exhibition, Westminster. Details, 1 Lowther Gardens, Prince Consort Road, London, SW7

18 JANUARY
Institution of Mechanical Engineers and British Welding Research Association Symposium **Pressure Vessel Research towards Better Design,** London

Chemical Process Design, Leeds, Northwestern branch meeting, Institution of Chemical Engineers

Digital computers in power system analysis, by P. P. Gupta and Professor H. Davies, 5.30 p.m., Institution of Electrical Engineers

19 JANUARY
Safety Aspects of Nuclear Propulsion, Southampton Technical College. Details, The Institute of Marine Engineers, 76 Mark Lane, London, EC3

The effect of nuclear radiation on metals, H. M. Finniston. Details, W. H. Lowther, North East Metallurgical Society, 5 Prestfield Avenue, Ladgate Lane, Middlesbrough.

24 JANUARY
Experimentation and reactor design in process research and development, W. Waddington and W. D. Betts, Institution of Chemical Engineers meeting, Birkenhead. Details, A. V. Bailey, 2 Finney Drive, Wilmslow, Cheshire

27 JANUARY
Some aspects of the solvent extraction of metal halides, A. G. Maddock, Windscale Club, Seascale, 8.00 pm

1 FEBRUARY
X-ray fluorescence, Burlington House, London, W1. Details, Society for Analytical Chemistry

Diffusivities in aqueous solution, Midland Hotel, Birmingham. Details, Institution of Chemical Engineers, Midland branch

Future Months

1–2 MARCH
Symposium on **User experience of large-scale industrial vacuum plant,** London. Details, Institution of Mechanical Engineers, 1 Birdcage Walk, London, SW1

21–26 MARCH
Electrical Engineers Exhibition, Earls Court. Details, Electrical Engineers, A.S.E.E. Exhibition Ltd, Museum House, Museum Street, London, WC1

5–7 APRIL
Electrical Contacts Symposium, London. Details, The Secretary, The Institute of Physics and The Physical Society, 47 Belgrave Square, London, SW1

10–15 APRIL
First International Congress on **Metallic Corrosion,** London. Details, Lt-Col. Francis J. Griffin, Society of Chemical Industry, 14 Belgrave Square, London, SW1

20 APRIL—4 MAY
Engineering, Marine, Welding and Nuclear Energy Exhibition, Olympia, London. Details, S. W. Bridges & Sons Ltd, Grand Buildings, Trafalgar Square, London, WC2

29 MAY—2 JUNE
Conference, **Property changes in reactor materials and radiation damage,** Bristol. Details, A. Trevor Churchman, CEGB, Berkeley Nuclear Laboratories, 7 St. Stephen's Avenue, Bristol 1

SEPTEMBER (*Date to be announced later*)
Convention on the **Impact of Nuclear Development on Electricity and on Instrument Techniques** To be held in London by The Institution of Electrical Engineers

20 FEBRUARY
The influence of availability of enrichment on reactor type and design, discussion, The Institution of Mechanical Engineers, 1 Birdcage Walk, SW1

OVERSEAS

27 FEBRUARY—3 MARCH
Conference on **Analytical Chemistry and Applied Spectroscopy** and Exposition of modern laboratory equipment, Pittsburgh. Details, W. F. Harris, Programme Chairman, Pittsburgh Conference, Westinghouse Electric Corporation Research Laboratories, Pittsburgh 35

17 APRIL
Conference to consider draft convention on **third party liability and indemnification resulting from operation of nuclear powered ships,** Antwerp. Arranged by Comité Maritime Internationale

15–20 MAY
IAEA **Nuclear Electronics** Conference, Belgrade.

21–24 JUNE
Fourth International **Light Metals** Congress, Leoben, Austria. Details, Montanistische Hochschule, Leoben, Styria, Austria

28 AUGUST—1 SEPTEMBER
International **Heat Transfer** Conference, Boulder, Colorado. Details, S. P. Kezios, c/o American Society of Mechanical Engineers, 38 West 39th Street, New York 18

1962

27 MAY—2 JUNE
Fourth International Congress on **Prestressed Concrete,** Rome and Naples. Organized by Fédération Internationale de la Precontrainte

20–26 OCTOBER
World Power Conference sixth plenary meeting, Melbourne

Industrial Literature

Silicone lubricants. Midland Silicones' booklet G14 outlines the properties and suggested applications of a range of silicone lubricating fluids and greases, particularly for use under arduous conditions.

★ 246

Gas drying. Birlec's publication No. 709 covers a selection of their range of fully automatic and manually operated adsorption dryers, designed for the removal of moisture from compressed air systems.

★ 247

Electrolytic capacitors. Technical specifications of the tantalum capacitors produced by Standard Telephones are given in a recent publication.

★ 248

Limit switches. A range of precision limit switches, of compact design and for heavy duty use, is described in Honeywell's catalogue 84.

★ 249

Machine tool control. Publication 1746/1, from Allen West, introduces a range of machine tool control gear that can be either separately mounted, cavity mounted or machine mounted.

★ 250

Servomotor accessories. Compiled for the synchro and servomotor user, the new Muirhead leaflet contains details and tables for mounting and zeroing all types of such equipment.

★ 251

Vacuum furnaces. Recent leaflets from GEC describe their range of vacuum induction furnaces suitable for melting and casting metals for sintering, brazing, etc., and the 'cold retort' type of vacuum resistor furnaces.

★ 252

Magnetic devices. A wide range of a.c. and d.c. operated relays, from miniature size to general purpose application, are specified in a revised catalogue from Magnetic Devices. It also includes solenoids and relay mountings

★ 253

Fuel cells. German development of a new hydrogen diffusion electrode for use with an oxy-hydrogen fuel cell, operated at ambient temperature and low pressure, is described in an English translation (report E-541) from Research Information Service of New York (price $95).

★ 254

Control boards. GEC's leaflet on component design for remote control boards has been revised to include more details of terminal sizes.

★ 255

Contact materials. For electrical contacts, the precious metal alloys available from Engelhard are grouped under platinum, palladium, silver and sintered materials. Properties and applications are thus given in their new catalogue.

★ 256

Mechanical valves. Pegler's have issued a new engineers' brass work catalogue that covers the gunmetal brass valves and cocks made as stock items.

★ 257

Mass spectrometer. In a recent bulletin, Consolidated Electrodynamics claim a new approach to analysis for their 21-110 spectrometer. It employs a very powerful mass-resolving system and, as a modular instrument, permits many different types of ion sources and ion detectors to be used.

★ 258

Seam welding. A brochure from Rockweld gives details of 'Circomatic' welding for storage tank construction, and includes a table of technical data for the preparation of various types of weld.

★ 259

Electronic control. Revised data sheets from Elcontrol cover current overload and underload relays, electronic counting and batching equipment, and the standard range of photoelectric units that now has a wider range of viewing heads and light sources.

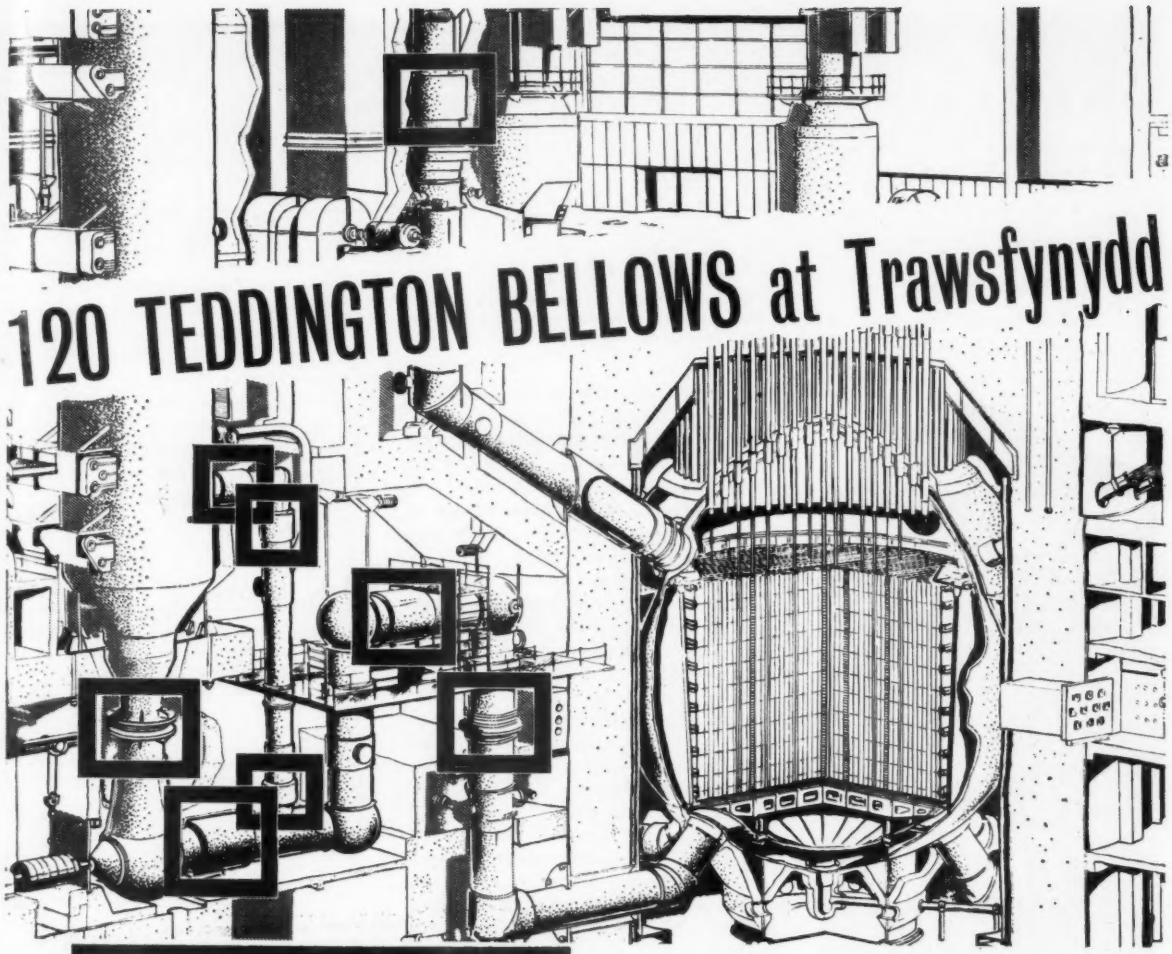
★ 260

Aluminium foil. Star Aluminium's recent brochure introduces the facilities available and the uses for high quality foil.

★ 261

★ *For further information on any item, circle the appropriate number on the reply card facing page 134.*

120 TEDDINGTON BELLOWS at Trawsfynydd



By courtesy of 'NUCLEAR POWER'

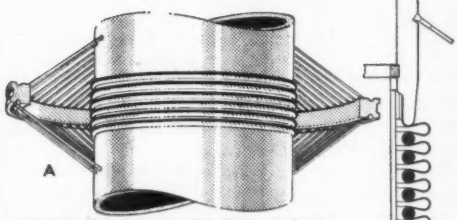


Illustration A represents one of the Teddington Stainless Steel Bellows supplied to Trawsfynydd with a novel form of restraint designed by Richardsons, Westgarth & Co. Ltd. (a member of Atomic Power Constructions Ltd.). This avoids the use of highly stressed hinge pins and permits a complete gimbal movement.

Illustration B indicates a section of Teddington Bellows, showing the restraining rings for extra strength which are a feature of this bellows design.

NO LESS THAN 84 BELLOWS 66″ diameter and 36 BELLOWS 42″ diameter, all of butt-welded stainless steel manufacture, are being fitted at Trawsfynydd to take up movement in the CO_2 cooling gas ducts.

Teddington secured this order only after many exhaustive tests including an accelerated life test equivalent to 20 years full operation. In addition, the larger size bellows were subjected to over-pressure tests of 1680 p.s.i.g. without developing a leak. Wherever pipe-work is subjected to vibration and movement in any direction owing to conditions of temperature and pressure, a Teddington bellows with a suitable end fitting will solve the problem. Write for full details of our range.

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(INDUSTRIAL BELLOWS DIVISION),
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Made under Licence from the Solar Aircraft Co. California, U.S.A.

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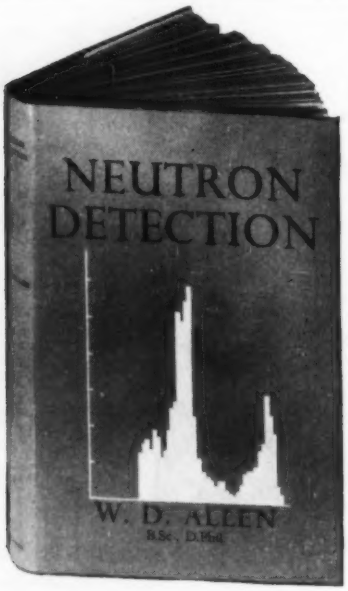
NEUTRON DETECTION

by

W. D. ALLEN

B.Sc., D.Phil.

Atomic Energy Research Establishment, Harwell



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NEWNES

★ 262

Book Reviews

High temperature corrosion

Third Metallurgy Symposium on Corrosion, Saclay, 1959 North Holland Publishing Co., Amsterdam, 1960: 240 pp Price 72s

The papers and discussions recorded in this book formed the substance of the metallurgical colloquium held at Saclay in mid-1959 held under the auspices of the French Atomic Energy Commission; previous colloquia having been devoted to recrystallization processes (1957) and solid state diffusion (1958).

To the nine papers devoted to various aspects of high temperature gaseous corrosion, Benard's review of recent developments provides a concise introduction. The discussion of diffusion mechanisms (Moore), the work on the selection of stainless steels for high temperature corrosion resistance (Genilloud), and the three papers on the morphology of oxide films (Paidassi), should all prove of interest to workers in the field of high temperature corrosion generally. Of the papers dealing more specifically with gas-cooled reactor problems, that on the attack of graphite by impurities in argon (Antill and Peakall) has already been published; that on the inhibition by HF of the corrosion of heated magnesium in moist air (Caillat, Darras and Le Clerq), presents a more detailed account of a topic briefly reported to the second Geneva Conference; and the study of the inflammability of magnesium and uranium in air and CO_2 (Darras, Baque and Le Clerq) is a welcome addition to the limited literature in this field.

Eleven papers are devoted to aqueous corrosion problems, and of these, three are specific to high temperature water systems, covering the influence of hydrogen on the corrosion of zirconium and its alloys (Wanklyn), the corrosion of stainless steels (Pouillard) and the stress corrosion cracking of Inconel (Coriu *et al.*). Factors affecting the aqueous corrosion of stainless steels are dealt with in review by Colombier, whilst papers on the precipitation of chromium carbide (Hatwell), the effect of annealing variables and carbon content (Plateau *et al.*) and 'knife-edge' corrosion in boiling nitric acid (Hochmann) deal with recent studies. Work on the mechanism by which hydrogen sulphide affects the corrosion of ferrous materials is discussed in two papers (Herzog; Le Boucher *et al.*), one using radioactive tracer techniques to establish the nature of the bonding between the metal surface and sulphur atoms. The contents are completed by papers on the use of the potentiostat (Berge and Jacquet) and on the work of the Biarritz Seawater Corrosion Testing Station (Hache).

The presentation of the book is good, as is the reproduction of the micrographs, but it is unfortunate that some of the papers are less well referenced than they might have been.

A. C. Littlejohn

New books

• *Disposal of radioactive wastes, Vol 1* Conference Proceedings, Monaco, 16–21 November 1959 International Atomic Energy Agency, Vienna 1960 Review Series No 4 (per HMSO)

★ 263

• *Heavy water lattices* International Atomic Energy Agency, Vienna 1960 142 pp Price 9s (per HMSO)

★ 264

• *Kernenergie-Technik* by H. Engel and K. O. Thielheim Verlag Modern Industrie, Munich 1960 300 pp Price DM36

★ 265

• *Computer abstracts (and Computer News)* issued monthly by the Technical Information Company Ltd, London

★ 266

• *Photo-electronic image devices* Proceedings of a symposium, London, September 1958 Edited by J. D. McGee and W. L. Wilcock Academic Press, New York and London 1960 397 pp Price $12

★ 267

• *Proceedings of the Fourth Conference on Carbon* held at the University of Buffalo, New York, June 15–19, 1959 Pergamon, London 1960 778 pp Price £7 10s

★ 268

• *Nuclear forces and the few-nucleon problem* Proceedings of the International Conference. London, 8–11 July 1959 2 volumes edited by T. C. Griffith and D. A. Power Pergamon, London 1960 Price £10

★ 269

• *Controlled thermonuclear reactions:* introduction to theory and experiment by S. Gladstone and R. H. Lovberg Van Nostrand, Princeton, New York and London 1960 523 pp Price 42s

★ 270

• *Analytical techniques for non-linear control systems* by J. C. West EUP, London 1960 223 pp Price 25s

★ 271

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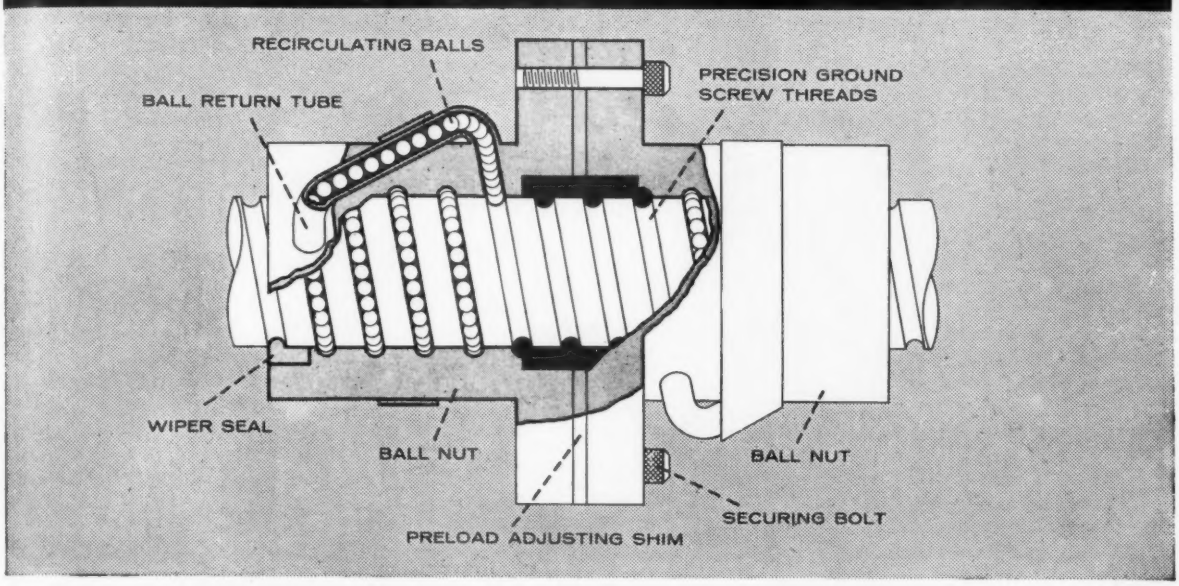
Beaver pre-loaded ball screws, up to 95% efficient, operate at -52°C to over 400°C with no backlash...



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Machined and ground to the highest standards of precision engineering Beaver pre-loaded ball screws greatly increase transmission efficiency. They reduce the power required for actuation by as much as 80%, when converting rotary drive into linear output or force input into torque output. By eliminating backlash, with pre-loading, they give precise control over very small increments of motion and a high response frequency. And when compared to conventional screw mechanisms, they provide a predictable operating life which is much longer, require much less maintenance and give more trouble-free operation.

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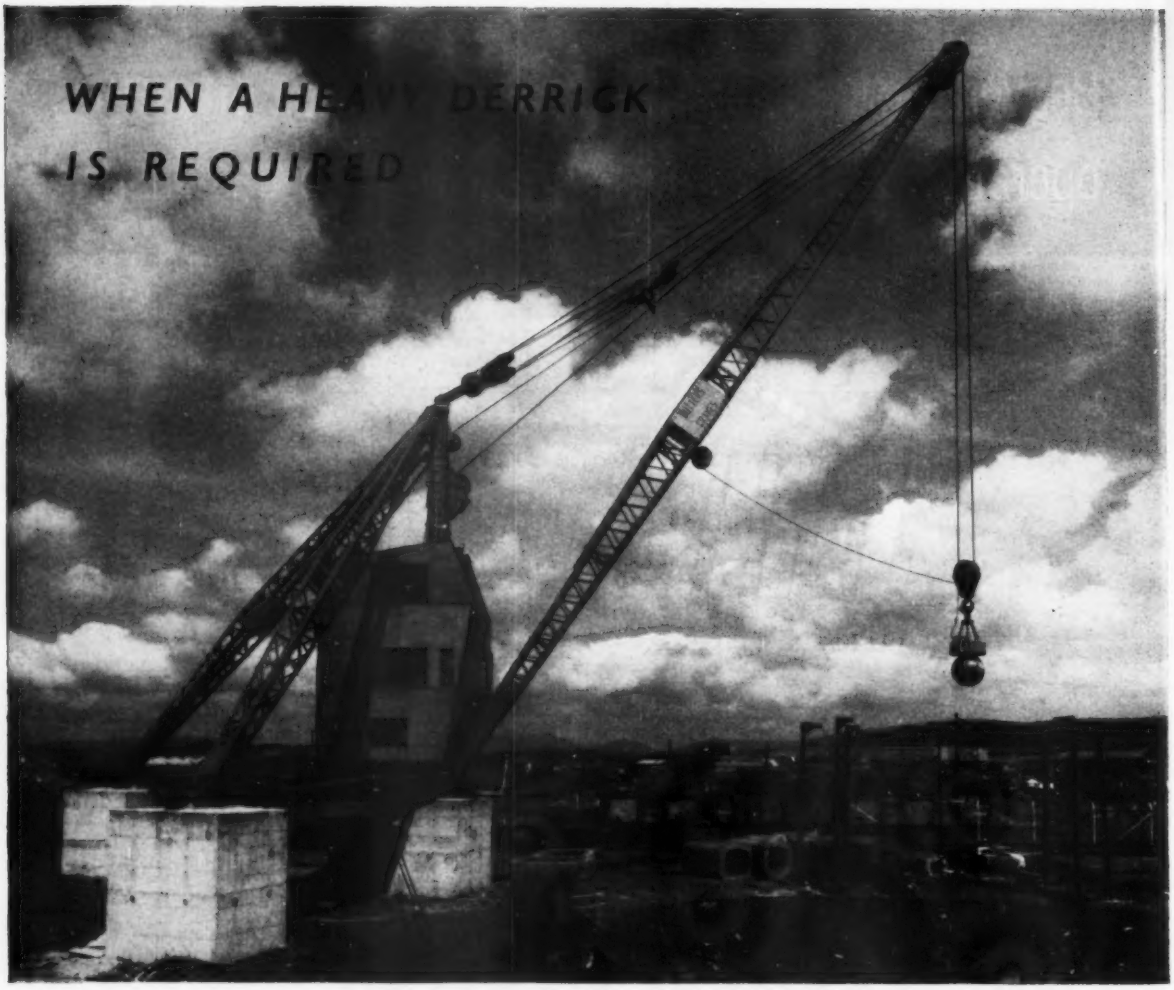

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The Model FN-1A Fast Neutron Counter—Scintillation Type—has three ranges, 0–50, 0–500 and 0–5000 neutrons/cm²/sec. It features an insensitivity to gamma radiation to 1 R/HR. Using a 2 in. diameter by ¼ in. thick ZnS plastic crystal, the instrument is splash proof, shock resistant and capable of operating up to plus 130 degrees F. High voltage power supply, amplifier-trigger and meter accessories are supplied on transistorized, plug-in cards.

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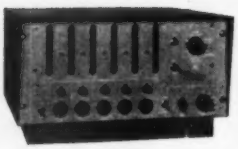

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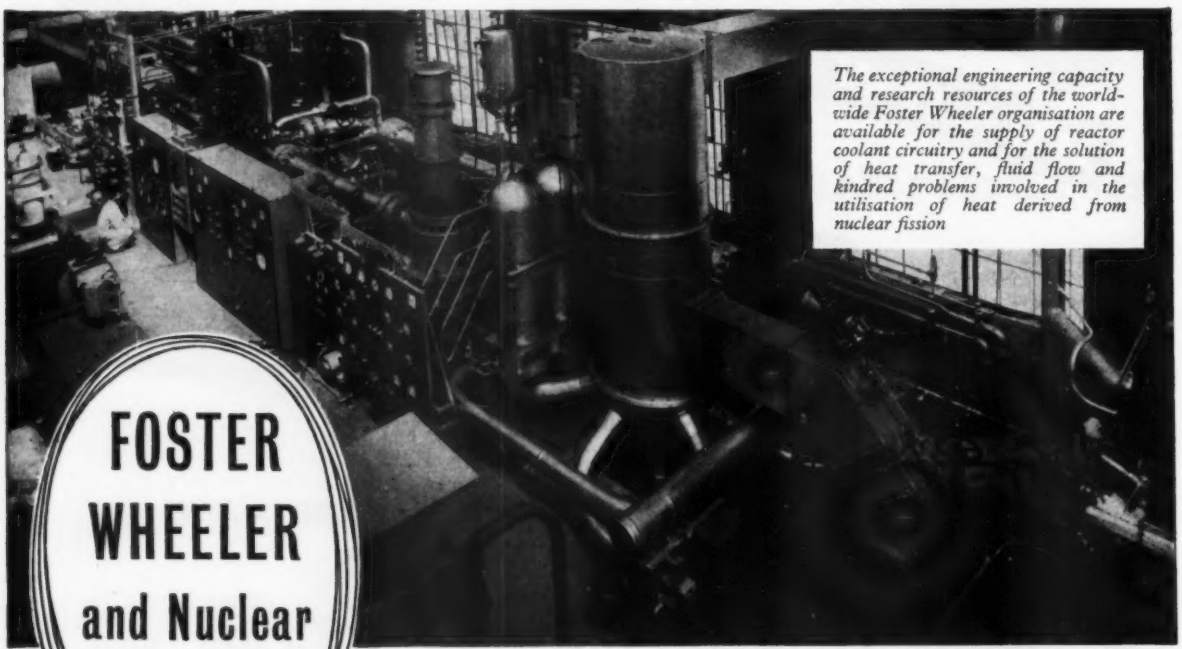

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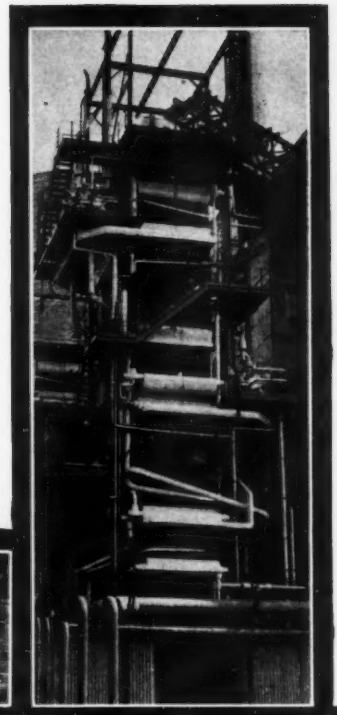
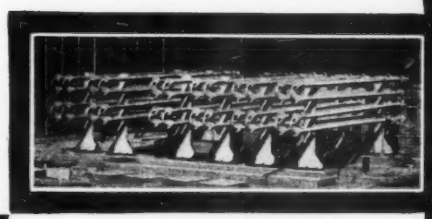
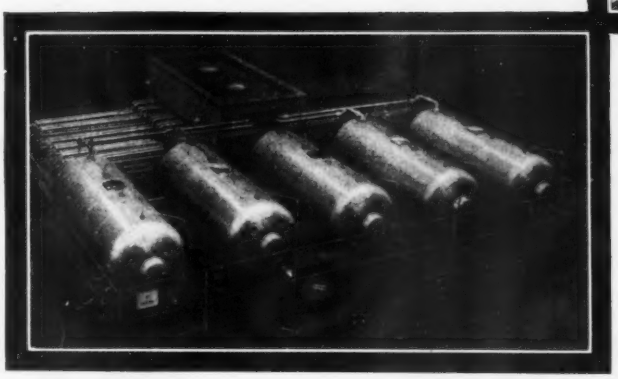




DCL know CO_2



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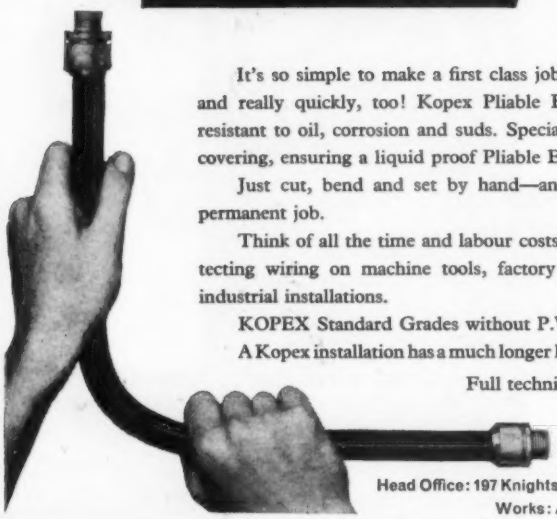

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Think of all the time and labour costs you save! It is especially suitable for protecting wiring on machine tools, factory equipment, chemical plants and general industrial installations.

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A Kopex installation has a much longer life than any other type of flexible connection.

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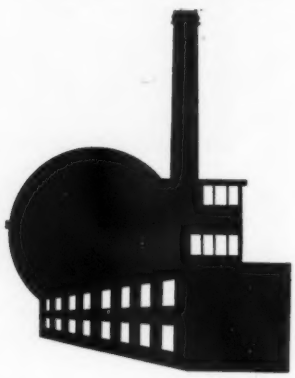

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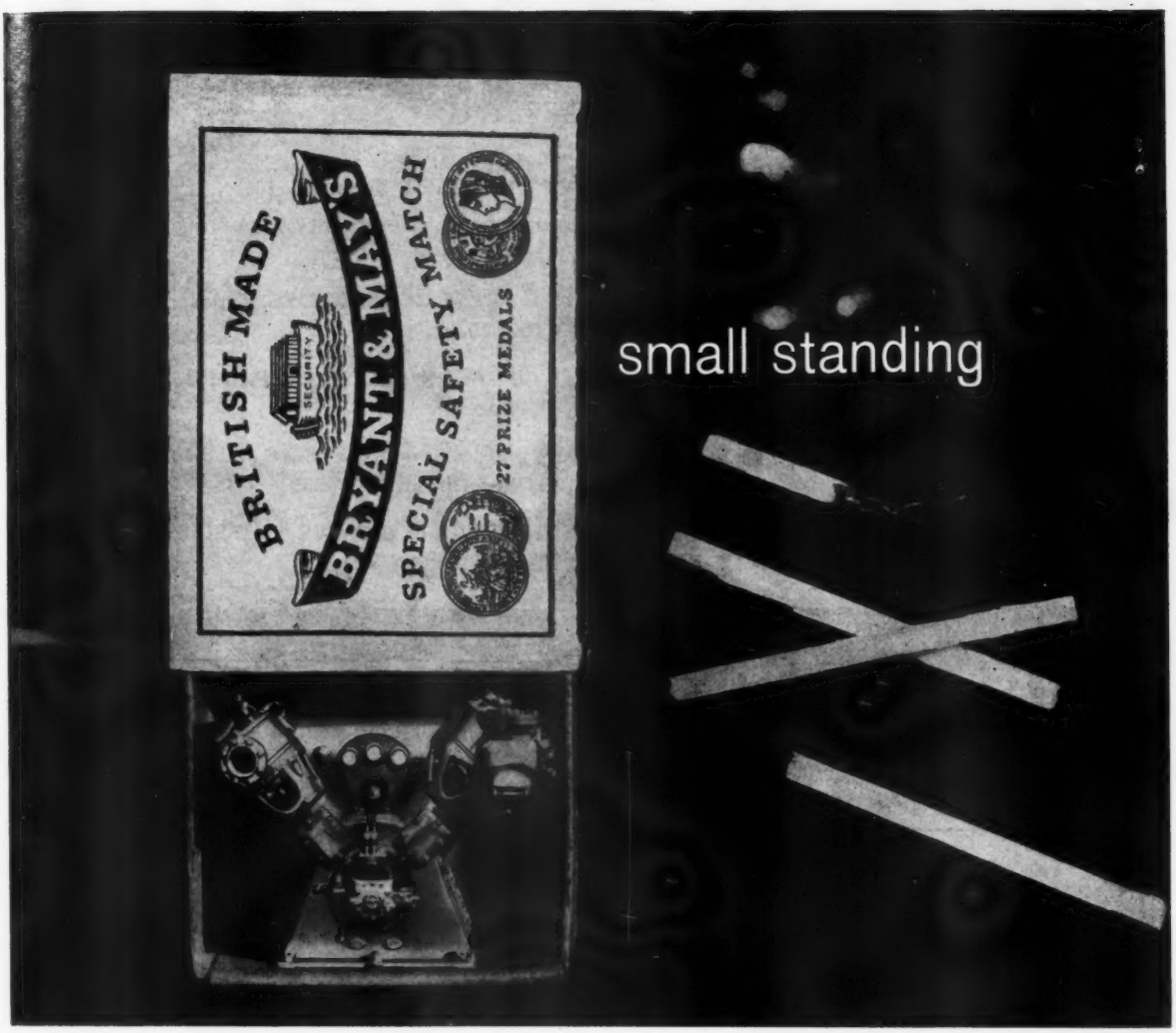

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Exacts less space — extracts more power. Match it against any other two stage industrial air compressor. You won't find one combining Vee-twin construction, flange-mounted motor and small floor space requirements in such striking degree.

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JOY-SULLIVAN LTD
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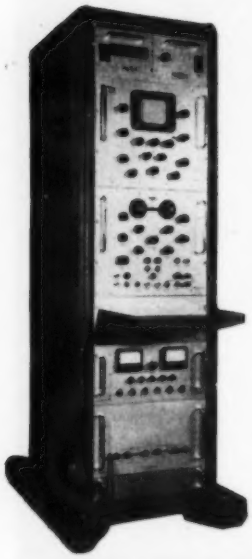
MARSHALL



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  A sophisticated instrument in the lower price range. Includes Scaler, Live Time Integrator and Print-Out.
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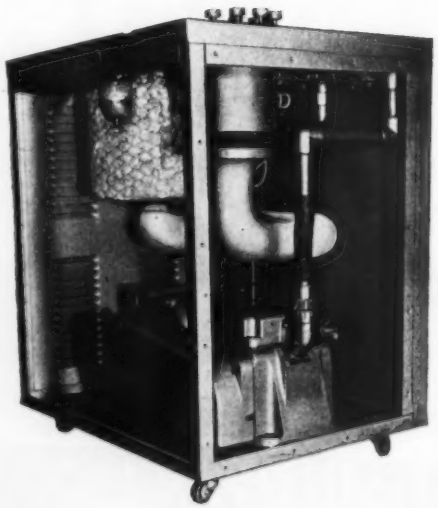
MARSHALL OF CAMBRIDGE ELECTRONICS LIMITED

THE AIRPORT · CAMBRIDGE · ENGLAND

RESIN IMPREGNATION

of wire-wound components under vacuum



N.G.N. new 'Resin-impregnating Plant' not only ensures better and far more thorough impregnation of all types of wire coils—its faster cycle of operation, coupled with carefully designed thermostatic control of vessels and pipework, plus full bore resin transfer valve, all combine to speed output while reducing costs.

Work chamber is evacuated to 1 micron Hg. to degas and dehydrate components which are then impregnated under a pressure of 80 lbs. p.s.i.

Surplus impregnant is completely recovered. Absolute reliability, both as regards thoroughness of impregnation and regular output is assured.

Enquiries for special plant to user requirements are especially welcome.

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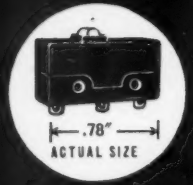
off the cuff . . .



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* No larger than the average cuff-link
* New mechanism has mechanical life of at least 10 million operations
* Three types of solder terminals available
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April 20 - May 4
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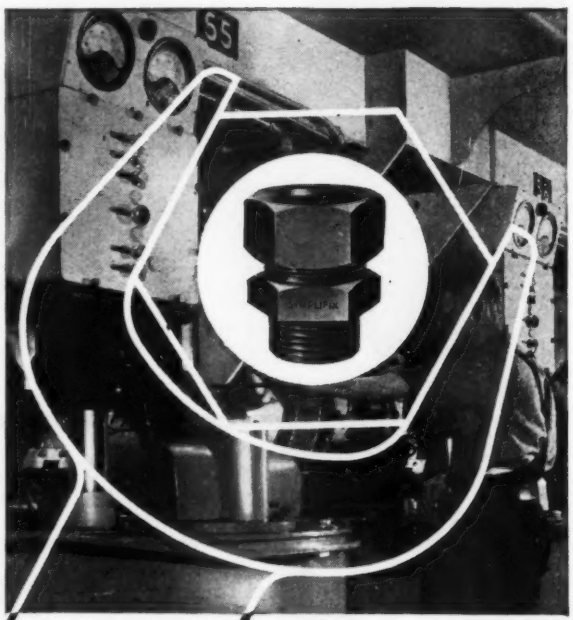
Engineers prefer SIMPLIFIX the foolproof coupling



The illustration shows centrifugal machines at the Plaistow Wharf Sugar Refinery of Tate and Lyle Ltd., where large numbers of Simplifix couplings are used

Simplifix—the sure and simple compression coupling for copper pipe. Perfect joints with almost all kinds of tubing, including those with very thin walls. No work to do on the pipe. Simply tighten the nut— the anti-friction washer prevents the pipe twisting. Manufactured since 1930, still the best. Millions in use. Made in sizes to suit tubing from ¼" to 2" O.D., in a wide range of interchangeable standard fittings. Non-standard fittings also made to order. Let us send you the Simplifix catalogue.

SIMPLIFIX

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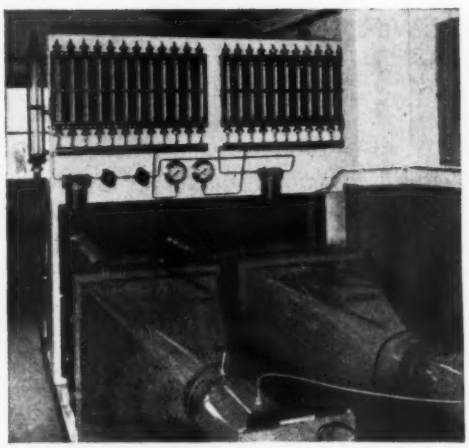
Vokes high temperature 'Absolute' filters



Vokes High Temperature 'Absolute' filters are tested in accordance with BSS. 2831 on the methylene blue test rig illustrated above. Every filter is subjected to a stream of air containing particles of methylene blue 'dust' ranging in size from 0·1 to 0·5 microns, and rejected if its efficiency is less than 99·99%. Vokes is the only British company which *guarantees* minimum performance figures in this way and Vokes filters are therefore widely used in all applications which require *scientific* filtration.

These filters have been designed for applications involving very high temperatures or risk of fire—for example in nuclear power stations where a breakdown in the filtration system due to an outbreak of fire might release dangerous toxic particles into the atmosphere.

They will withstand temperatures up to 1,000°F and are available in standard sizes as manufactured for the Atomic Energy Authorities. Similar in appearance to the 55 'Absolute' panels from which they were developed, Vokes high temperature filters have an all-glass paper filter medium with aluminium separators, refractory sealers and metal frames. The efficiency of this type of 'Absolute' is even greater than the very successful '55' panel, giving a penetration of only 0·01% against a methylene blue dust cloud.

A booklet on Vokes special purpose air filters is available on request.

The APPROVED filter for fire resistant applications

(Pat. applied for)

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—always at hand

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Please write for full details of Balteau and Pantak equipment up to 500 KV.

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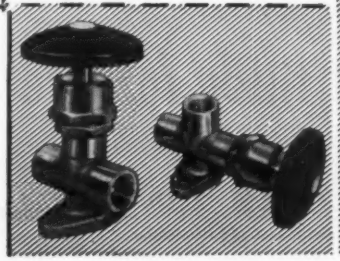

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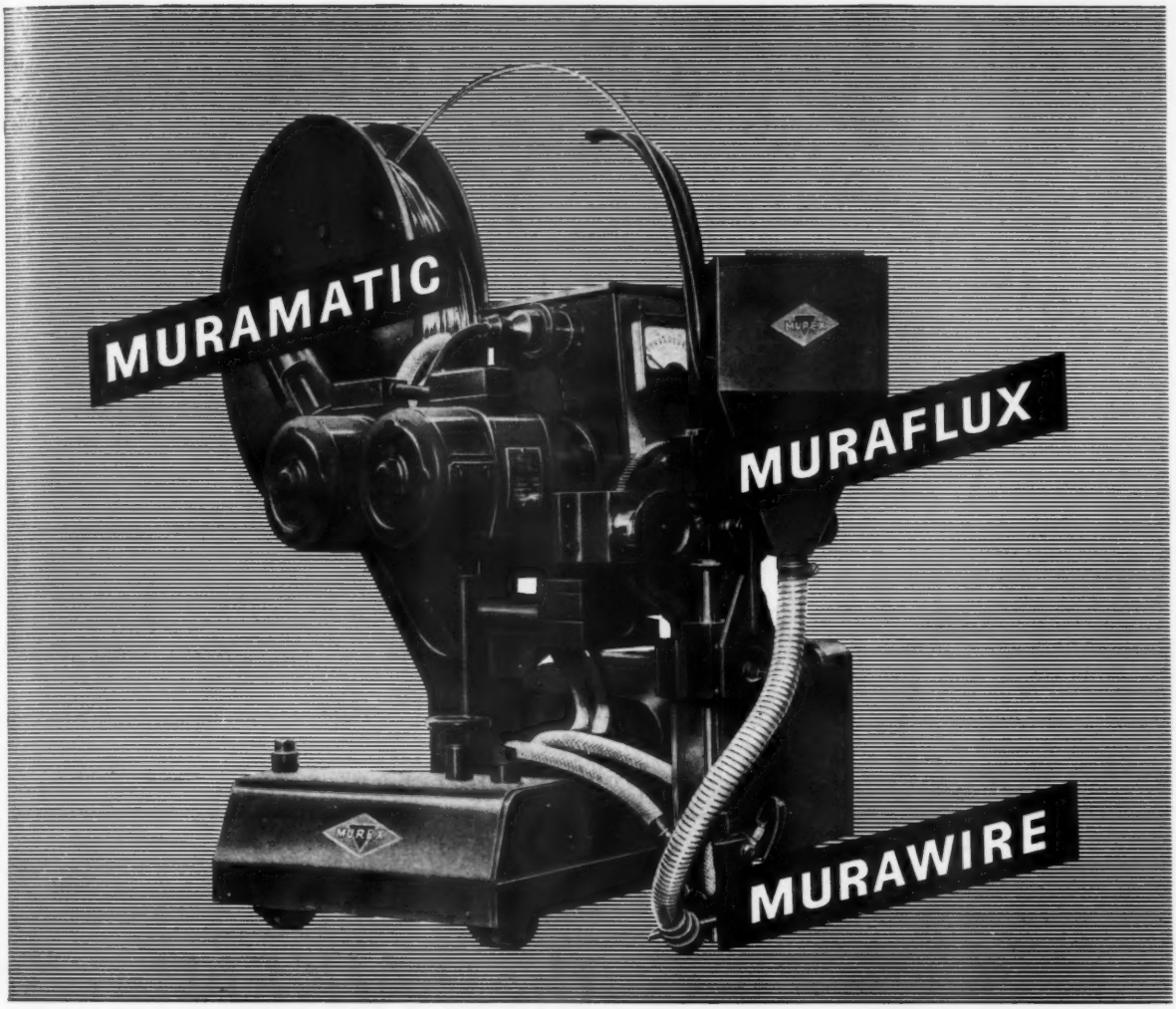

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"COILEX" flux coated wires in various grades for welding by the open-arc process.

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ANCILLARY EQUIPMENT for positioning, turning and manipulating work varying in weight from 1 cwt. to 200 tons.

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A complete service for automatic welding

MUREX WELDING PROCESSES LTD. WALTHAM CROSS, HERTS.

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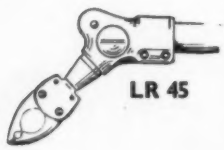

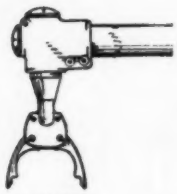

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This model has Jaw Rotation through 400° by remote control from the handle section, and is available up to 12 feet in length.

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- FULL CLEAR BORE •
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- GREASE LUBRICATED SEATING •
- TOROIDAL SEAL FOR SPINDLE •
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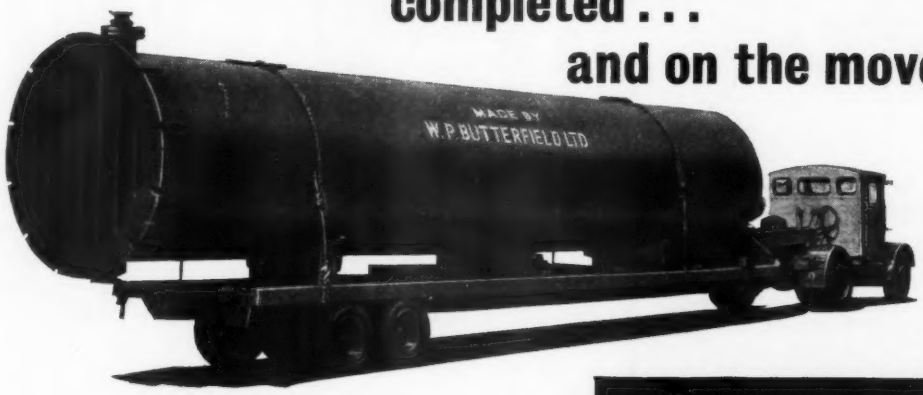

Our illustration shows a Vertical Alkylation Reactor, 7' 6" I/D by 45' 8" overall height, fabricated from ¾" thick Mild Steel B.S.14 plate, having a welded dished and flanged top plate and a ⅝" thick bottom plate, stiffened with 10" x 5" rolled steel joists. All flanges on the vessel are lined and faced with Hastelloy " B ".

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MILD STEEL PLANT

including Tanks, Pressure Vessels, Vacuum Vessels, etc.

Butterfields also produce such equipment in Stainless Steel, Aluminium Aluminium Bronze Alloy Nickel and Nickel Alloys as well as

in Mild Steel to any of the recognised codes This includes the highest specification demanded by Nuclear Energy Establishments

fabricated to the exacting demands of the Nuclear Engineer by

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Where purity is not related to mortality, but to the removal of adulteration from a substance, Aerox Porous Ceramic Materials and Filter Units are the guardians supreme. Removal of solids from fluids; oil or moisture from air lines, and particles from gases are operations dealt with effectively by Aerox Filters. Aerox Ceramics have many other applications.
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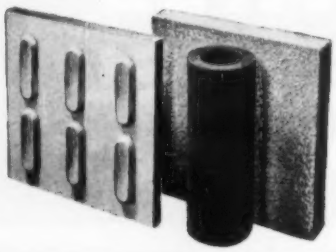

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Hopkinsons' "Tansphere" butterfly valves for gas-tight isolation duties between the reactor and steam generating plant are on order for the Latina Nuclear Power Station, Italy.

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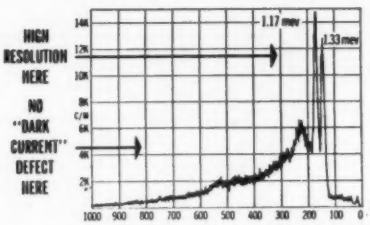
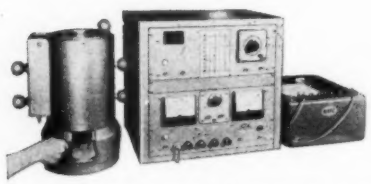
This NMC Gamma Spectrometer Eliminates "Dark Current" Defect

Combines Better Resolution With Greater Precision Over Wider Range Than Any Other System At Any Price

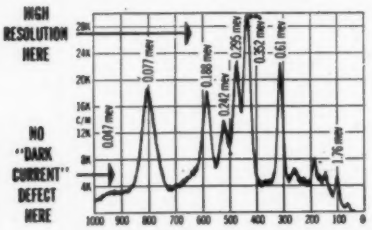


Actual spectrogram of Cobalt-60 made with a GSS-1. Window No. 3. Time constant: 2 sec.



A complete gamma spectrometer system NMC model GSS-1

This greatly simplified system features regulated high voltage supply as part of the counting ratemeter auto-scan system . . . all-transistorized probe amplifier and spectrometer circuits . . . and solid or well-type crystal. These points and the actual spectrograms shown here tell only part of the story. For full details, write.



Actual spectrogram of Radium made with a GSS-1. Four runs over a period of 20 hours with no adjustment of instrument between runs, demonstrating utmost stability. Range: 30,000 C/M. Time constant: 3 sec.

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Nuclear Measurements Corp.

International Office:
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hollow plastic

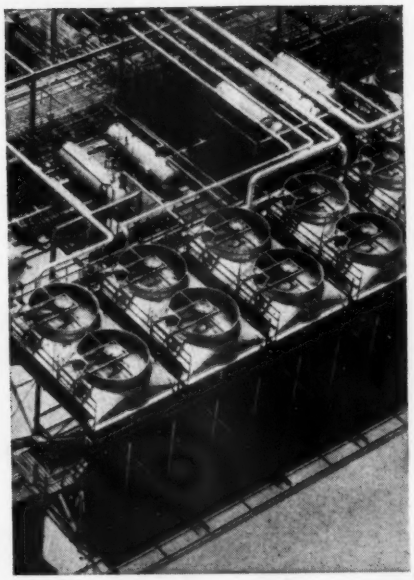
INDUSTRIAL FANS

for oil,

gas and chemical plant,

process cooling

and ventilation



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These fans have shown substantial practical and economic advantages over conventional types in the course of several years of operation under a wide variety of different conditions. Initially available in overall diameter sizes of 6 ft. to 14 ft. in increments of 1 ft.

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MAR 274

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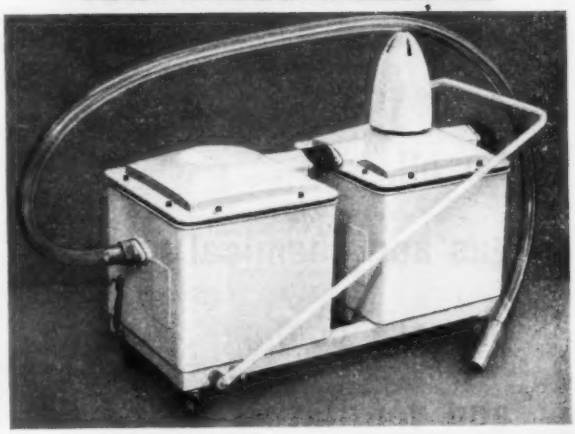

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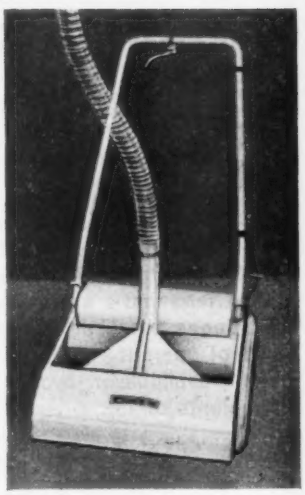
By action of the powerful suction unit, dust laden air, at 100 cu. ft. per minute, is drawn through the primary filter to extract all particles above 2 micron size, and into the Absolute cell with 100% filtration of particles down to 0.3 micron. Major contamination is retained in a polythene liner for easy and safe destruction.



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21	44	67	90	113	136	159	182	205
22	45	68	91	114	137	160	183	206
23	46	69	92	115	138	161	184	207

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209	215	221	227	233	239	245	251	257
210	216	222	228	234	240	246	252	258
211	217	223	229	235	241	247	253	259
212	218	224	230	236	242	248	254	260
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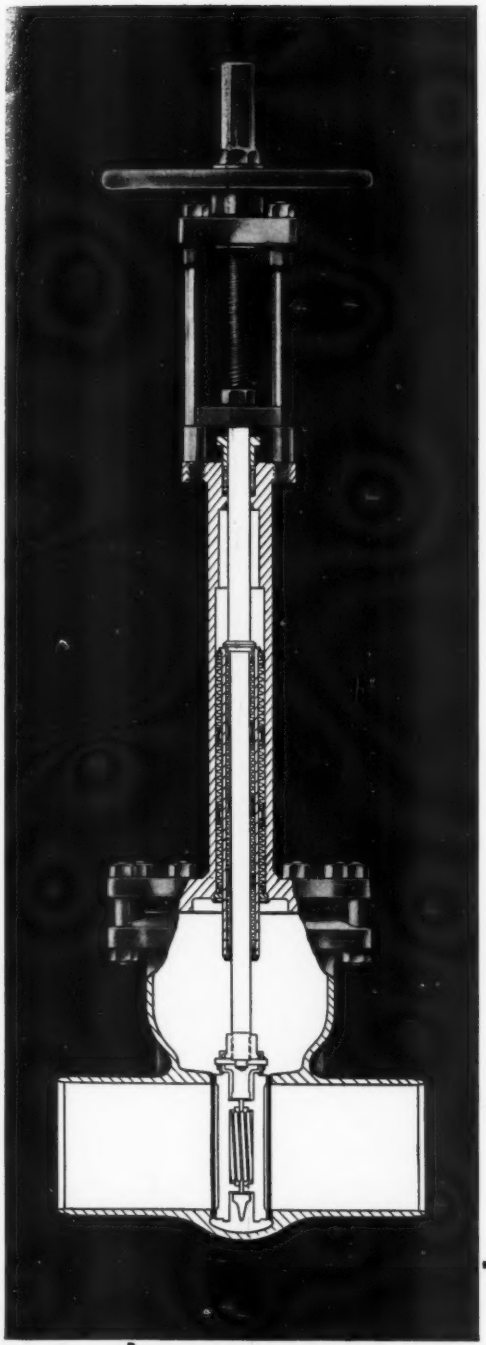

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#220 DATA HANDLING UNIT usable as an active timer, event counter and readout device ... effective or actual counting times may be selected from 0.1 to 999.9 minutes in 0.1 min. steps ... manual, semi- or fully automatic operation, destructive and non-destructive readout.

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The Model CN-110 digital computer assembly ... only 8¾" high ... weighs 30 lbs. with plug-in ... operates on 25 watts

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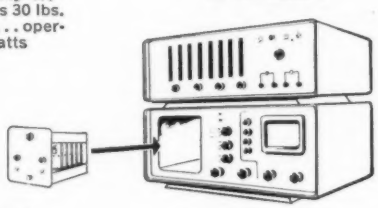

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Becomes a different pulse analyzer every time you change the logic

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Write for the new 6-page bulletin which contains complete details of the CN-110 and all accessories.

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Knowing where to find the answers on

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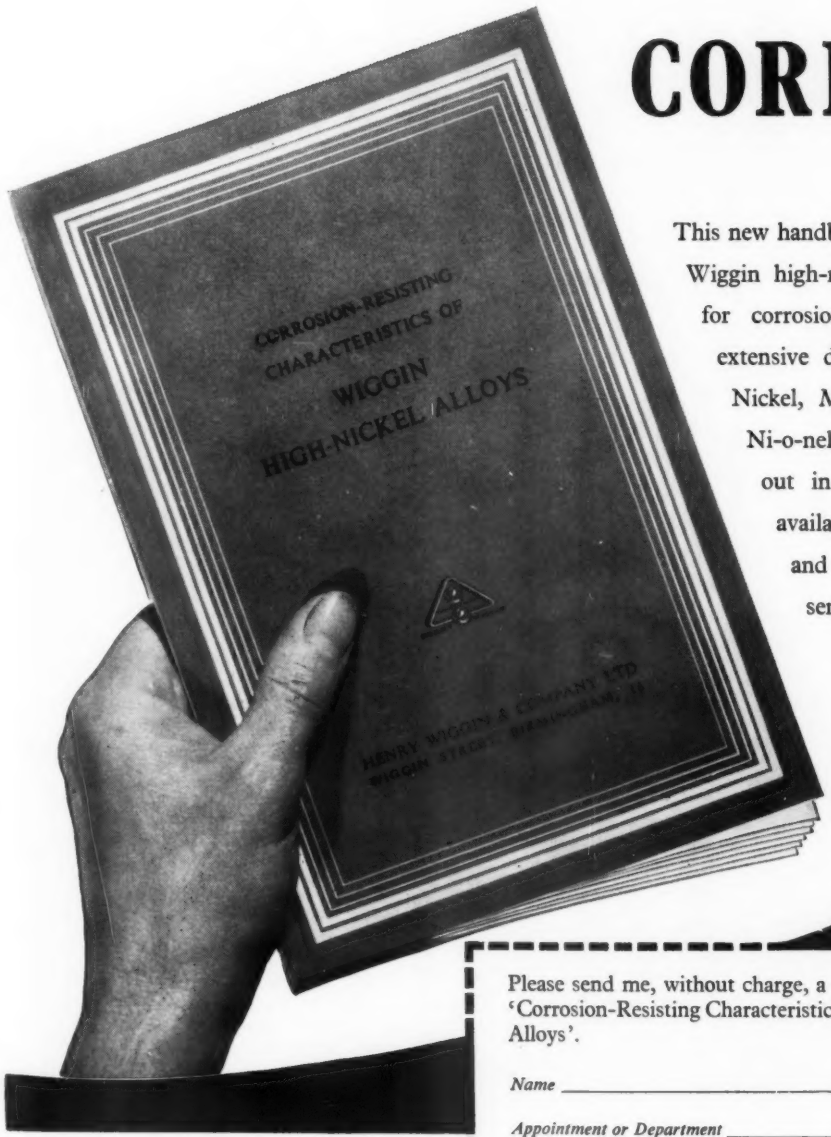

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"The Furnace requires considerable cooling and the demand for an unfailing water supply has been met by constructing a large capacity Braithwaite pressed steel storage tank at high level."

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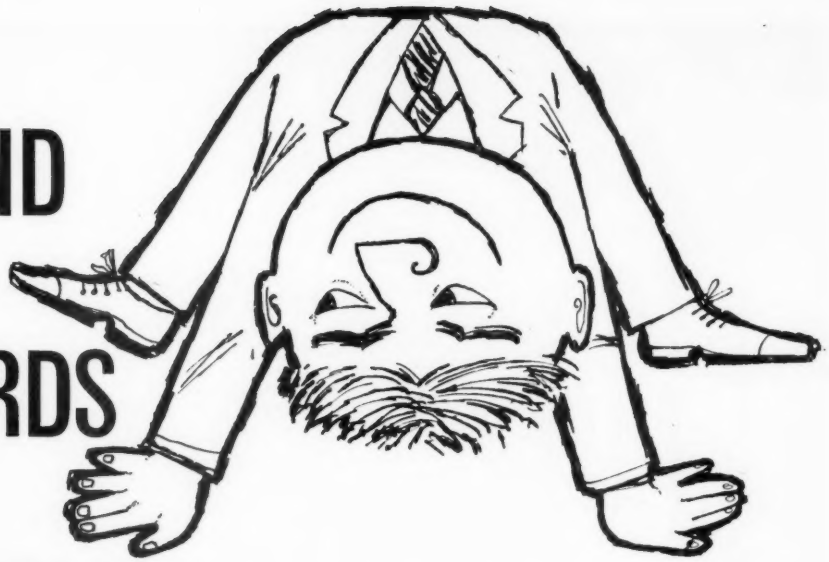

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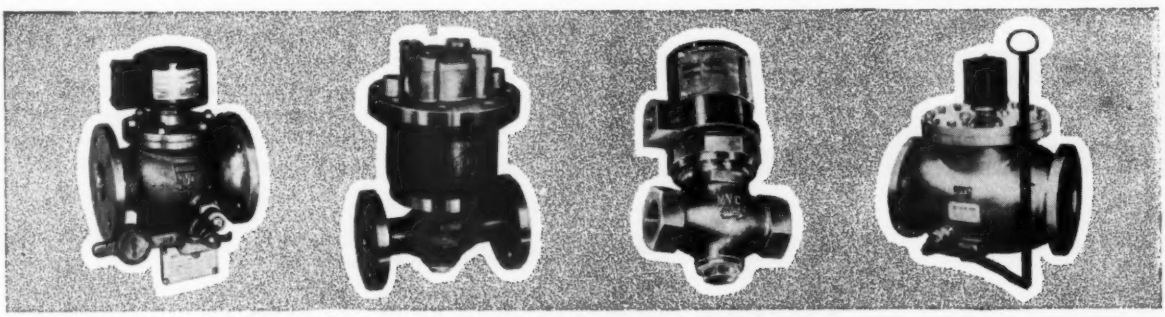

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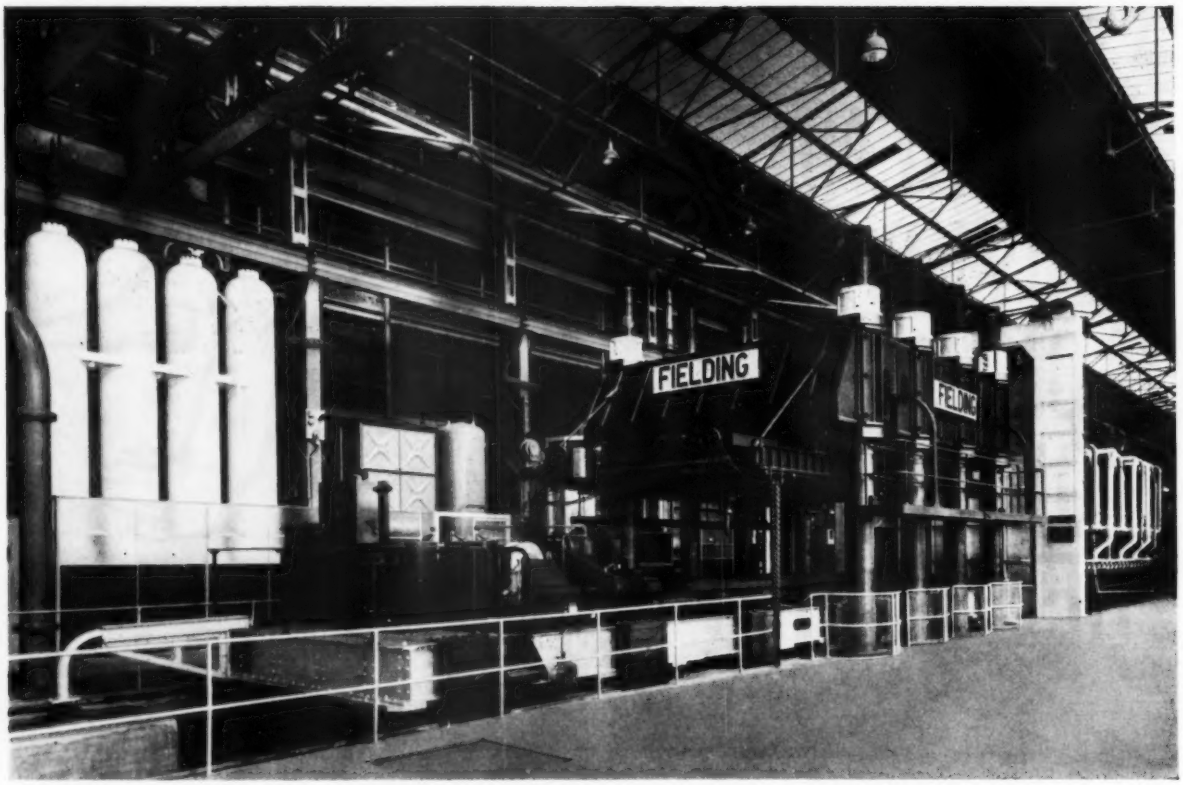
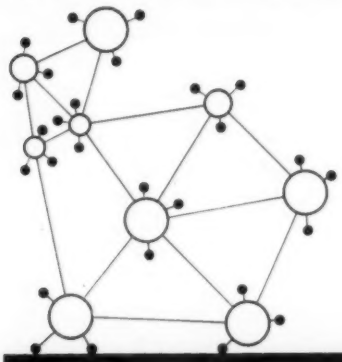


This press has been supplied to the Whessoe Company of Darlington for the shaping of the heavy steel plates required for the shells of the large reactor pressure vessels of nuclear power installations.



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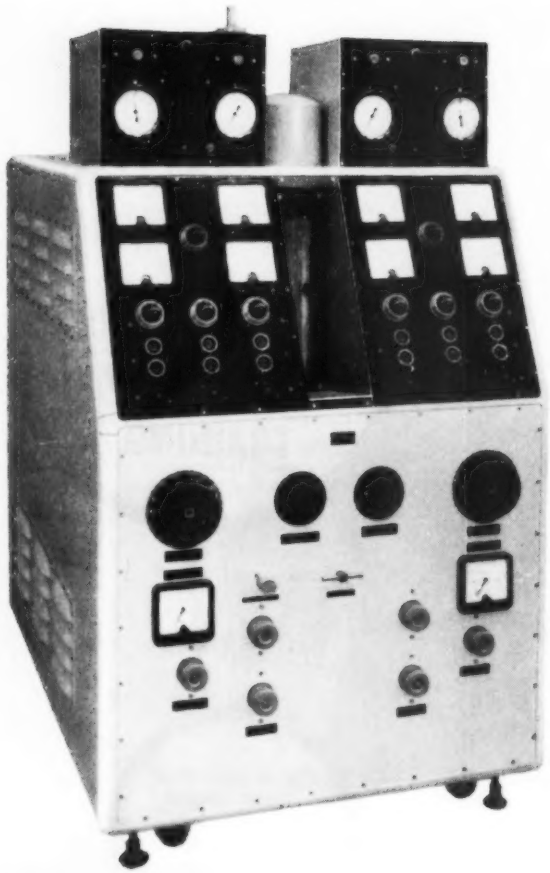

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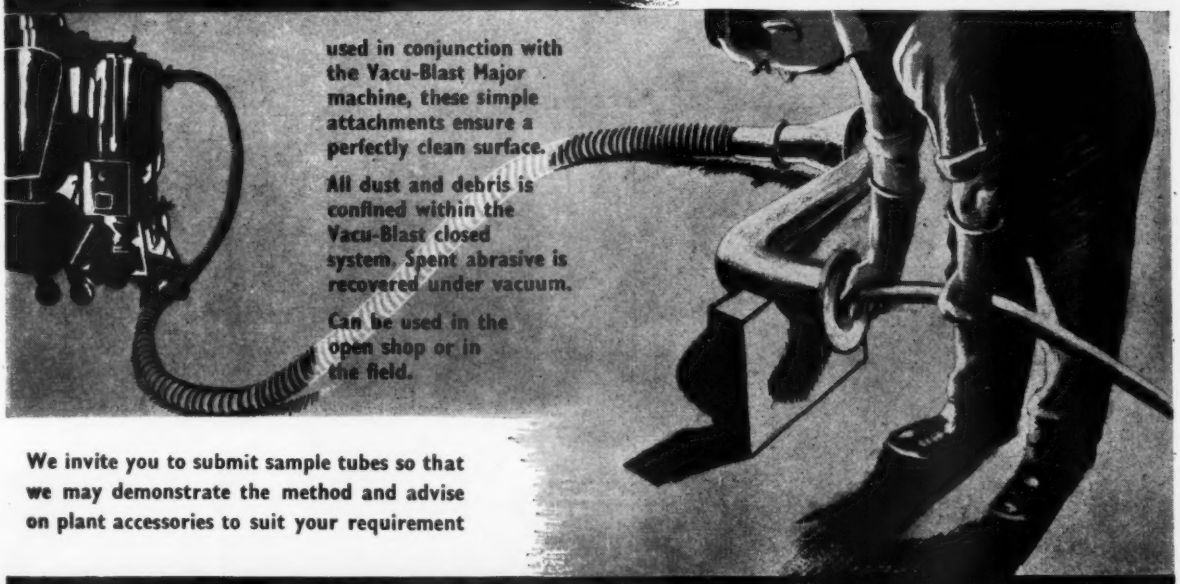

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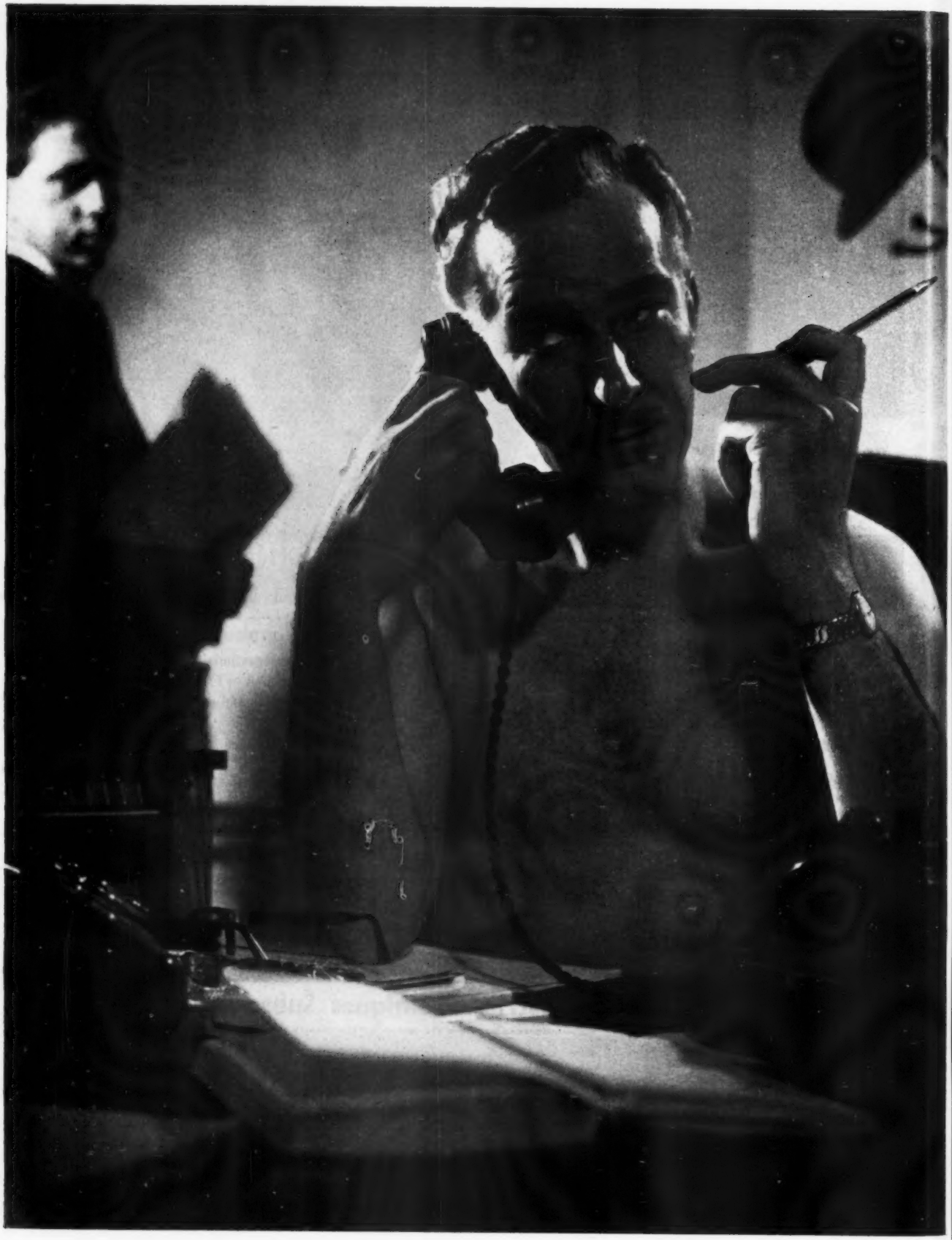

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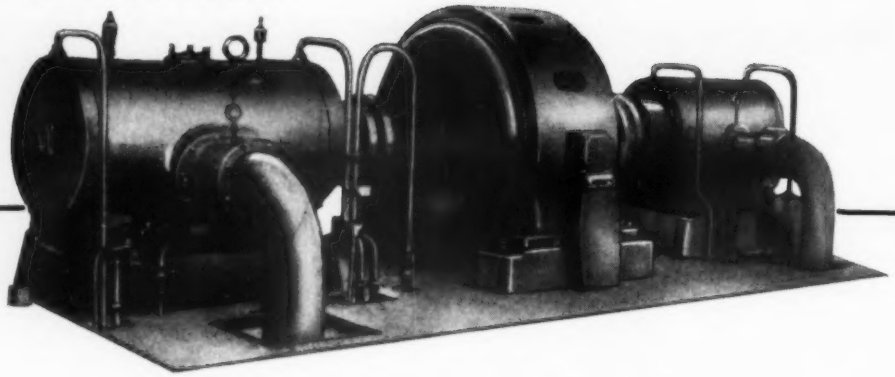

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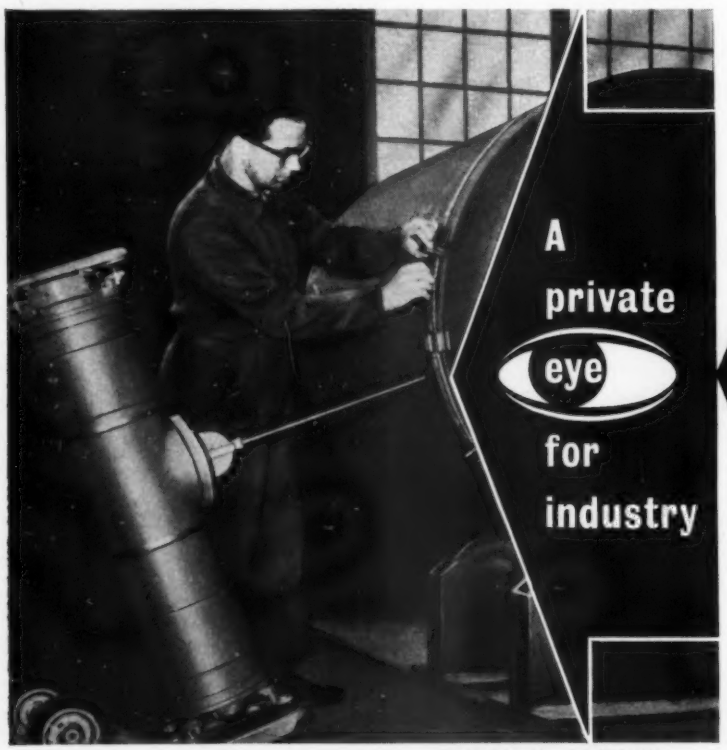

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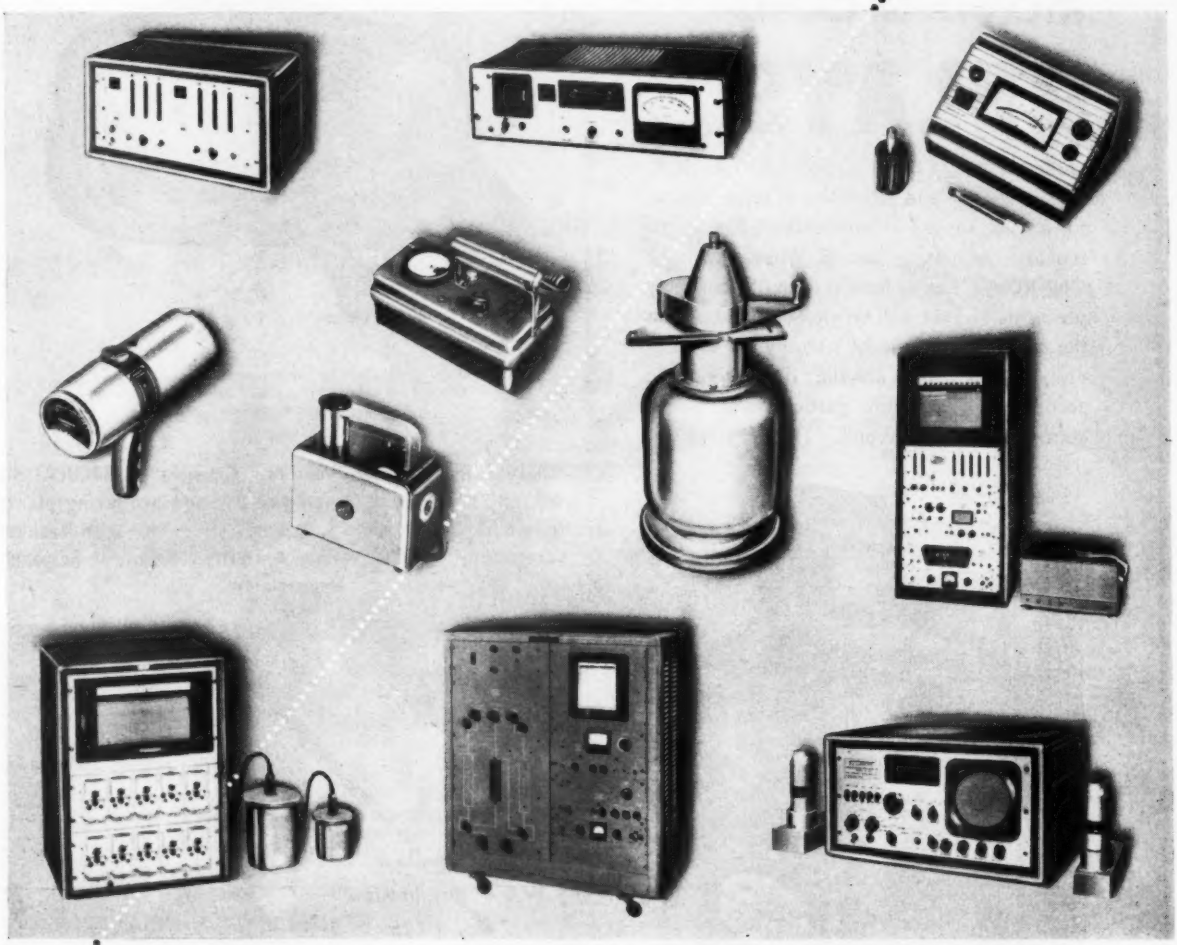

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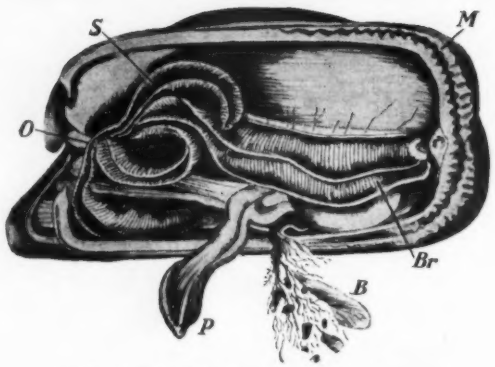

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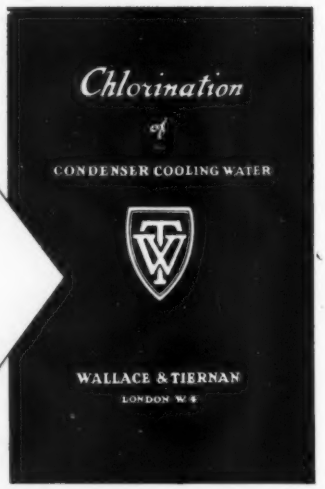

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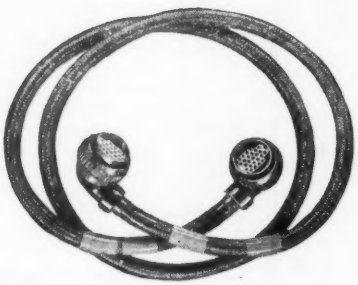

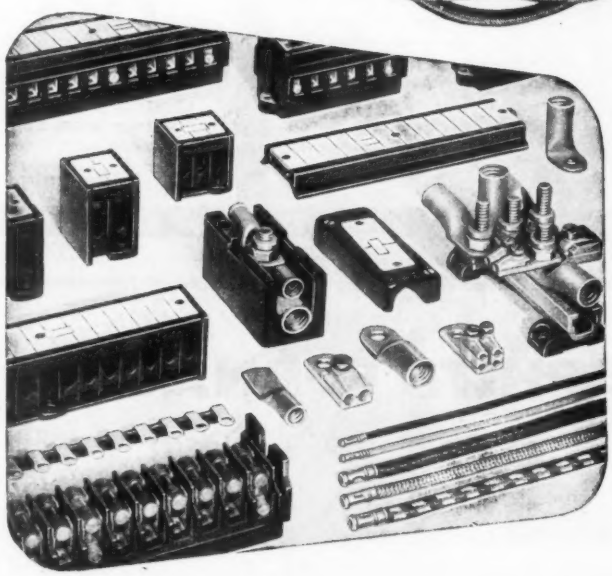

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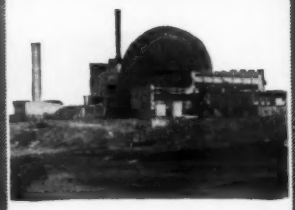

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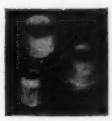

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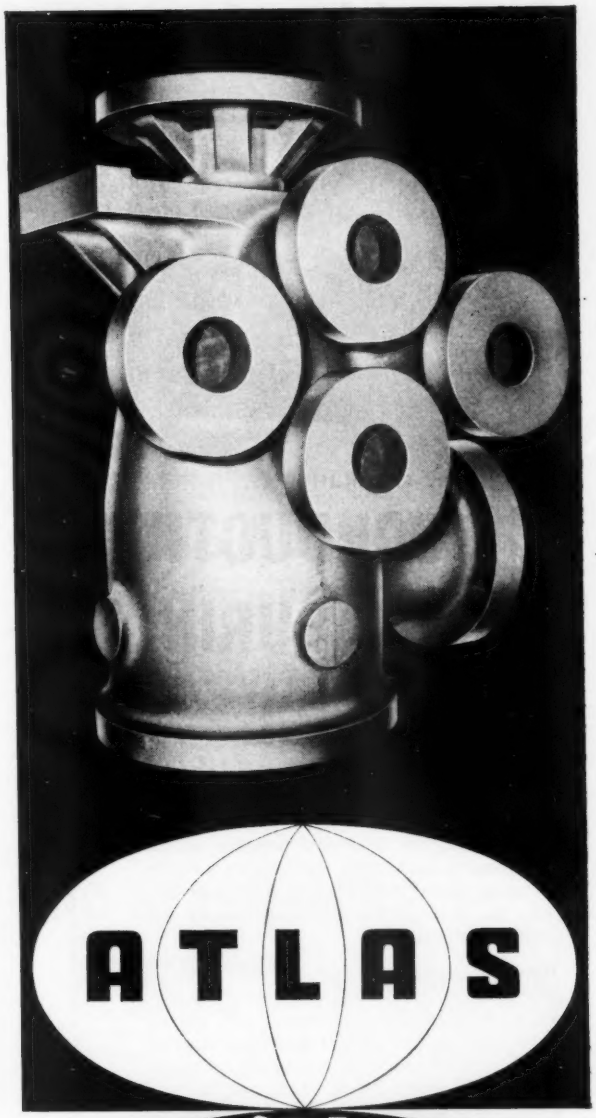

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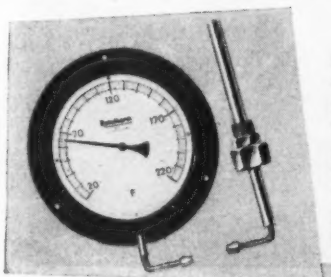

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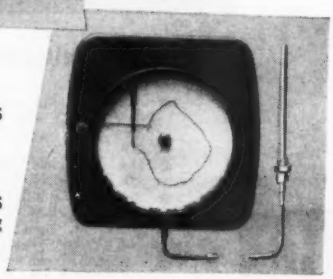

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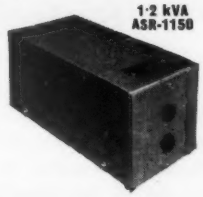

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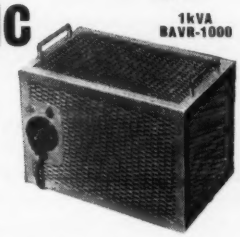

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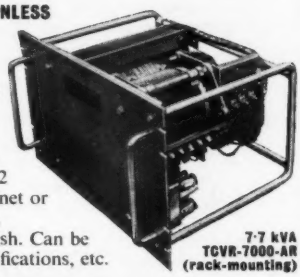

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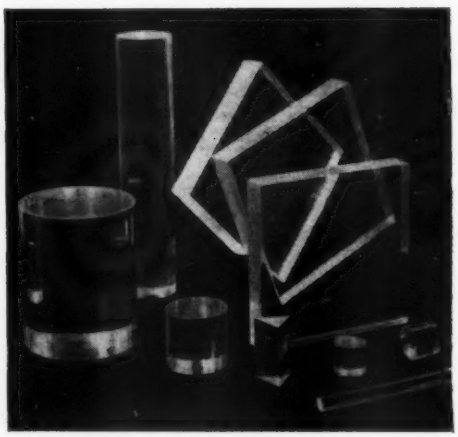

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required by the United Kingdom Atomic Energy Authority, Production Group, Springfields Works, Salwick, Preston, Lancashire, to lead and direct a small team of Chemists and Assistants engaged on laboratory and small pilot scale development of chemical processes associated with extraction of uranium from ore; production of uranium metal, oxide and other intermediates; recovery of values from a wide range of complex residues and treatment of effluent liquors. The work involves considerable study of the chemistry underlying processes used in this large modern Works, which has responsibility for extraction of uranium from ore and concentrates and its fabrication into a wide variety of fuel elements for nuclear reactors.

At least a second class honours degree, or equivalent, in Chemistry, together with wide research experience in physical and inorganic chemistry, are essential. Development experience, including a period as section head or team leader, on operation and control of small pilot plants used in chemical process work, is desirable.

Salary between £1,740 and £2,460 according to age, qualifications and experience. Housing Assistance Schemes, Contributory Superannuation.

Send postcard for application form, quoting reference SF.79/J.28, to Works Secretary at above address.

Closing Date: 31st December, 1960.

UNITED KINGDOM ATOMIC ENERGY AUTHORITY
require
EXPERIMENTAL STAFF

to assist in the development of radiation electronic equipment. The work includes Health Physics Monitor development, Nuclear Radiation Spectrometry and the application of semi-conductors to radiation measurement. Previous experience of pulse techniques and transistor circuitry is desirable and experience in the detection and measurement of ionising radiations would be an advantage. Applicants should preferably possess a pass degree or H.N.C. Where necessary training in specialised radiation techniques may be given.

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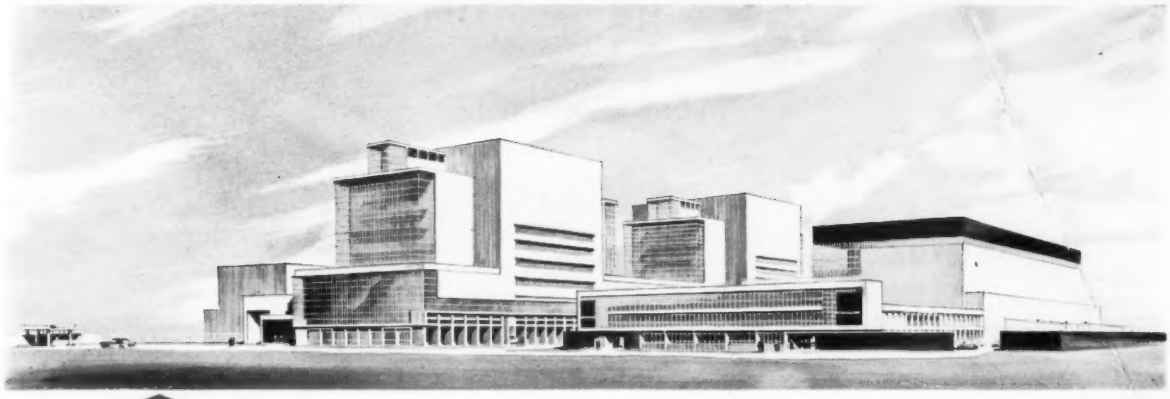

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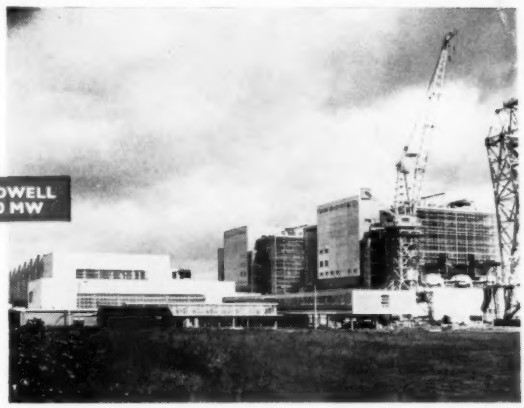

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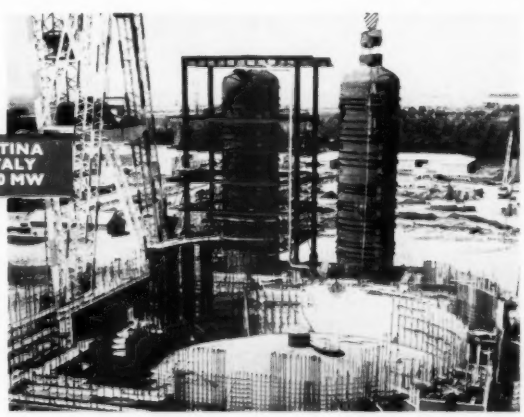

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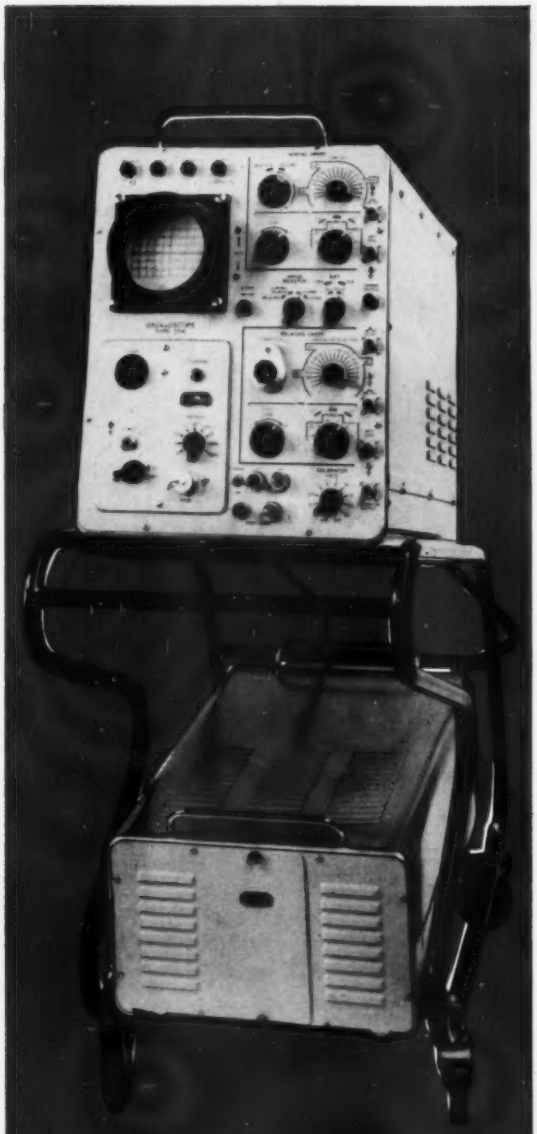

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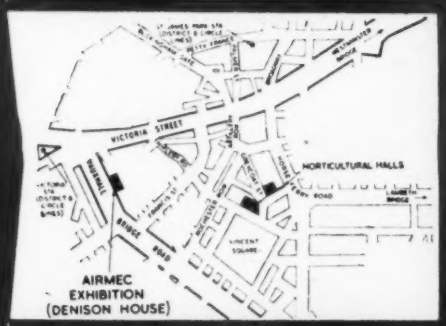

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